DOCUMENT RESUME

ED 296 100 CE 050 297

TITLE	Research and Development. The Illinois Plan for Industrial Education.
INSTITUTION	Illinois State Univ., Normal.
SPONS AGENCY	Illinois State Board of Education, Springfield. Dept. of Adult, Vocational and Technical Education.
PUB DATE	87
NOTE	123p.; For related documents, see CE 050 288-298.
AVAILABLE FROM	Curriculum Publications Clearinghouse, Horrabin Hall 46, Western Illinois University, Macomb, IL 61455.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; Data Collection; *Design; *Industrial Education; Information Sources; Junior High Schools; Learning Activities; Lesson Plans; *Manufacturing Industry; Middle Schools; *Research and Development; *Research Methodology; Statewide Planning; Technical Education; *Technological Literacy; Technology; Testing

ABSTRACT

This guide, which is one in the "Exploration" series of curriculum guides intended to assist junior high and middle school industrial educators in helping their students explore diverse industrial situations and technologies used in industry, deals with research and development. The following topics are covered in the individual lessons: product identification and analysis (basic steps in creating a new product, developing a product profile, and assessing company limitations); information collection and research (types of research, steps in conducting a research project, and information sources); procedures for developing a preliminary design; techniques in selecting and refining a design; steps in specifying a design; procedures in building and testing a prototype; and steps in presenting a design for approval. The guide includes the rationale behind its development, hints to the teacher, lesson plans, student handout masters, teacher aids, a unit examination, and a list of references. The lesson plans include cross-referenced lists of objectives, lesson content, and learning activities. (MN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

The Illinois
Plan for Industrial
Education

Illinois
State Board of
Education

Adult,
Vocational and
Technical Education

ED296100

RESEARCH AND DEVELOPMENT

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

Minor changes have been made to improve reproduction quality.

Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

P Sedma

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

CE050297

PACKET INCLUDES:

- Rationale
- Hints to the Teacher
- Lesson Plans
- Student Handout Masters
- Teacher Aides
- Unit Examination
- References

ILLINOIS PLAN FOR INDUSTRIAL EDUCATION

Exploration Curriculum Development Initiative

Project Director

Dr. Franzie Loepp
Illinois State University
Normal, Illinois

Associate Director

Kenneth Welty
Illinois State University
Normal, Illinois

Writing Team Participants

Sharon Brusic
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia

Mark Coleman
Chute Middle School
Evanston, Illinois

Daryl Floit
Morton Junior High School
Morton, Illinois

Dennis Gallo
O'Fallon High School
O'Fallon, Illinois

Mark Hobson
Normal Community High School
Normal, Illinois

Marvin Hodel
Morton Junior High School
Morton, Illinois

Merlin Mathewson
Bartonville, Illinois

Barrett Smith
Sycamore Junior High School
Sycamore, Illinois

INTRODUCTION

"Research and Development" is one of a series of curriculum materials developed for junior high and middle school industrial educators. Listed below are the titles of the units in the series.

Communication
- Using the Language of Industry
- Exploring Computer Technology
- Exploring Photography
- Exploring Graphic Communication
- Exploring Electronic Communication

Energy Utilization
- Exploring Solar Energy
- Using Alternate Energy Sources
- Conserving Energy Sources
- Exploring Electricity/Electronics
- Exploring Mechanical and Fluid Systems

Impact of Industry and Technology
- Recycling Materials
- Limiting Pollution
- Exploring Careers in Industry and Technology
- Exploring Technology and the Future

Production
- Exploring Materials and Processes
- Exploring Construction Technology
- Research and Development
- Exploring Manufactured Systems
- Servicing Products

Transportation
- Exploring Land Transportation Systems
- Exploring Aviation Technology
- Exploring Water Transportation Systems
- Exploring Space Transportation Systems
- Exploring Materials Handling Systems

With the Exploration Series, industrial educators can lead their 7th and 8th grade students in exploring many industrial situations and technologies used in industry. In addition, this series can serve as a resource for teachers orienting 9th and 10th grade students to industrial technologies in communication, production, energy utilization and transportation. Each unit in the series includes a rationale, hints to the teacher, a sample daily schedule, lesson plans, student handouts, teacher aids, a unit examination, and a list of references.

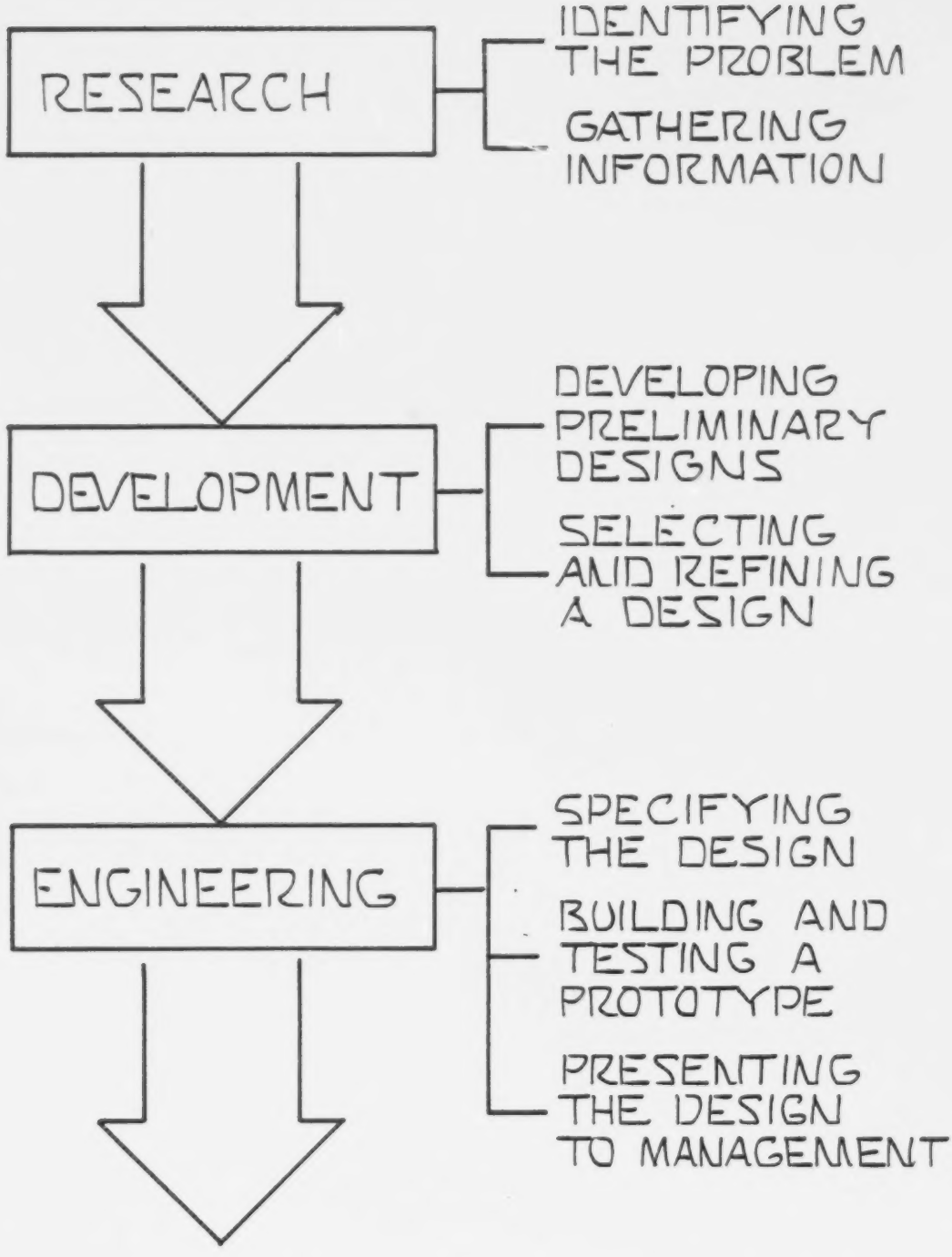
"Research and Development" and other units in the series are available on a cost recovery basis through the Curriculum Publications Clearinghouse, Western Illinois University, Horrabin Hall 46, Macomb, IL 61455.

The development of this publication was made possible through grants from the Illinois State Board of Education, Department of Adult, Vocational and Technical Education, Research and Development Section, 100 North First Street, Springfield, Illinois 62777. Opinions expressed in this document do not reflect, nor should they be construed as, policy of the State Board of Education or its staff.

RATIONALE

Throughout everyday life and the world of work, people are confronted with problems that need to be solved. The goal of research and development is to identify problems, gather the information needed to solve the problems, and develop solutions to problems. The products we purchase and use everyday are the direct result of research and development activities. To be active and informed members of our industrial and technological society, students need to understand basic research and development processes.

The study of research and development provides an excellent context for developing problem solving skills. During this unit, students will be able to experience how to identify a problem, research a problem, and develop a solution to a problem. While learning how industry solves problems, students will learn how to generate, refine, implement, test, and communicate ideas. This unit will provide a basic foundation for further studies in technologies and problem solving.


RESEARCH
IDENTIFYING THE PROBLEM
GATHERING INFORMATION
DEVELOPMENT
DEVELOPING PRELIMINARY DESIGNS
SELECTING AND REFINING A DESIGN
ENGINEERING
SPECIFYING THE DESIGN
BUILDING AND TESTING A PROTOTYPE
PRESENTING THE DESIGN TO MANAGEMENT

HINTS TO THE TEACHER

1. This unit is designed to precede the manufacturing unit. During this unit, your students will be working in groups and developing a variety of new product ideas. At the end of this unit, each group will present their new product idea to the rest of the class. After the presentations, your students can vote on the product they would like to mass produce during the manufacturing unit. You may want to announce and use this product selection process to create competition and to encourage teamwork.

2. Today's technologically sophisticated products are not the result of one person's research and development activities. To provide students with an accurate research and development experience, it is important that students work in teams of about three to four students. You may want to appoint or elect a design team leader for each group. In addition, you may want to encourage each design team to establish their own identity by creating a mock research and development firm that has its own name and logo.

3. During this unit, your students will be writing problem statements, gathering information, answering research questions, drawing thumbnail sketches, drawing a final product sketch, and developing working drawings. To help students organize their research and development activities, you may want to require that each team keep a research and development notebook. At the end of the Research and Development unit, each team can turn in their notebook for a final evaluation. You may want to consider building on a notebook during the manufacturing unit. At the end of the manufacturing unit, your class can develop a comprehensive notebook to enter in a local, state, or national manufacturing contest.

4. During this unit, you will need to show students examples of thumbnail sketches, rough sketches, renderings, mock-ups, working drawings, and prototypes. You may want to develop these examples yourself, and/or collect them from local industries.

5. Throughout this unit, you will need a variety of materials to facilitate learning activities. Prior to implementing this unit, you may want to review the unit thoroughly, identify the materials you need to purchase, and organize the materials for each learning activity.

6. To ensure student success, encourage students to keep their products simple. The primary objective of this unit is to expose students to the research and development process. The product is meerly a means to enable students to experience this process. The quality of the learning experience is far more important than the quality of the product produced.

7. This unit represents an excellent opportunity to promote technology education in your school community. Invite guest speakers to talk to your class about research and development in their industry. Invite parents, administrators, the press, and fellow educators to your students' project presentations. Video tape your students' project presentations to show at open houses and during student recruitment activities. Enter your students' research and development activities in your local, state, or national project fairs or competitions.

Unit: Research and Development

Lesson 1: Identifying the problem

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: - list the basic sequence of steps used to create a new product. - describe the role of design specifications when creating a new product. - list the six basic types of company limitations. - describe the purpose of a product profile.	A. Identify the problem 1. Basic steps for creating a new product. a. identify the problem b. gather information c. identify possible solutions d. identify the best solution e. specify the design f. make a prototype g. test and modify the prototype h. present the new product to management 2. Product profile includes: a. problem statement b. design specifications c. company limitations 3. Company limitations a. human b. facility c. time d. information e. financial 4. Primary considerations a. consumer demand b. profit potential c. competition d. production capability	A. Teacher Guided Discussion 1. Ask students to list some of their wants and needs. Discuss how products play an important role in meeting those wants and needs. 2. Using CT #1-1, discuss the 8 basic steps in creating a new product. 3. Discuss how problems can be identified through observation. 4. Discuss the importance of being able to define a problem accurately. 5. Discuss the role of design specifications. 6. Discuss how company limitations must be taken into account when solving a problem. Using CT #1-2, discuss the six basic types of company limitations. 7. Using CT #1-3, discuss the four basic primary considerations that have to be taken into account when selecting a new product.	TA #1-1: Identifying the Problem CT #1-1: Basic Steps CT #1-2: Company Limitations CT #1-3: Primary Considerations

B. Following a demonstration in a lab activity, students will be able to: - identify a specific problem through observation. - develop a product profile that includes a problem statement, a list of design specifications, and a list of company limitations.	B. Problem identification and analysis. 1. observation 2. problem identification 3. develop a product profile a. write a problem statement b. list design specifications c. identify company limitations	Learning Activity 1. Create a situation that includes a variety of problems. 2. Ask students to identify one of the problems. 3. Using the identified problem, demonstration how to develop a product profile that includes a problem statement, list of design specifications, and a list of company limitations. 4. Provide each student HO #1-1 and divide the class into groups of three to four students. 5. Have each group identify a new problem and develop a product profile. 6. Circulate around the room and provide individual instruction as needed. 7. When the students have completed the lab activity, have one student from each group present their product profile. 8. Provide students with feedback regarding their product profiles. 9. Collect and evaluate each teams' product profile.	HO #1-1: Identifying the Problem

IDENTIFYING THE PROBLEM

Preparation Hints:

1. Prior to implementing this lesson, you will need to create a situation that features a variety of problems that students can observe and identify. For example, clutter your desk with a variety of video tapes, computer diskettes, business cards, reference materials, drafting tools, overhead transparencies, and small hand tools. At an appropriate time during the lesson, pretend to be frustrated looking for a specific item. At this time, students should be able to offer a variety of suggestions for solving your organizational problem.

2. Review the materials provided, duplicate HO #1-1, and prepare the transparencies needed to present the lesson.

3. To introduce this unit, you may want to consider obtaining and showing a video tape or film that features research and development or problem solving in industry.

4. During the lab activity, your students will need to identify their problem solving limitations. Prior to implementing this lesson, you will need to identify the tools, materials and machines that students will have access to during the research and development and manufacturing units.

Content Presentation Hints:

1. Introduce students to the idea that many new products are designed to be answers to life's little problems. List a variety of products on your chalkboard. Include items like a microwave oven, a portable vacuum cleaner, and a cordless phone. Ask students to identify problems that may have caused research and development people to create these products.

2. Consider inviting a guest speaker from a local industry to come in and present how their research and development department identifies problems and creates new products.

Learning Activities Hints:

1. Using the business card example listed in HO #1-1 or similar problem, explain how to complete the product profile.

2. Team work is an important part of the research and development process in industry. Today's technologically sophisticated products can rarely be attributed to one person's research and development activities. Therefore, it is important that students work together in teams of about three to four students. While each team member should receive HO #1-1, you may want to provide each team an extra product profile that will be collected and evaluated.

3. Do not be alarmed if two or more teams identify the same problem for their research and development project. Even though they are addressing the same problem, it is highly unlikely that they will develop the same solution.

4. While students are completing their product profile, circulate around the room, providing individual instruction as needed. Try to visit each team at least three times, once to check their problem statement, another time to check specifications, and the last time to answer questions regarding limitations.

5. After each team has completed their product profile, ask a team member from each group to report the contents of their product profile. Encourage the students to ask questions after each product profile presentation.

Basic steps for creating a new product:

A. problem identification
B. gather information
C. identify possible solutions
D. identify the best solution
E. specify the design
F. make a prototype
G. test and modify the prototype
H. present the new product to management

OT #1-2

Company limitations

A. human
B. facility
C. time
D. information
E. financial

OT # 1-3

Primary considerations

A. consumer demand
B. profit potential
C. competition
D. production capability

IDENTIFYING THE PROBLEM

Discussion:

People have a variety of wants and needs. Many of our wants and needs are fulfilled by the products we purchase and use every day. We purchase food to meet our need for nourishment, houses to meet our need for shelter, and automobiles to meet our need for transportation. The goal of people who work in research and development is to create products that satisfy our wants and/or needs. In addition, these products need to be able to make a profit for the company.

New products do not just magically appear, they evolve. Typically, the evolution of a new product begins with a problem. The people in research and development follow a basic series of steps when creating a new product. These steps are listed below.

1. Identify and analyze the problem
2. Gather information about the problem
3. Develop a list of possible solutions
4. Select the best solution
5. Specify the design
6. Make a prototype
7. Test and modify the prototype
8. Present the new product to management

The first step in the process is to identify and analyze the problem. Problems are basically opportunities to improve our quality of life. To identify a problem, we can observe life around us and look for ways to improve it. For example, you are talking to a sales person in a store about purchasing a stereo system. The sales person understands your needs and has been very helpful. Before you purchase a system, you want to shop around a little more. However, you want to be able to ask for this sales person if they prove to have the best price, so you ask for a business card. The sales person looks through their wallet, pockets and desk drawers before finding a business card behind the sales counter. Once you leave the store, you think to yourself, "I should not have had to ask for a business card, I should be able to just pick one up at the sales counter."

Before a problem can be solved, it must be understood. The first step in understanding a problem is to define it accurately in the form of a problem statement. An appropriate problem statement for our business card example would be:

> to design a device that displays and dispenses business cards on a sales counter or desktop.

The next step in understanding the problem is to analyze it and make a list of design specifications for solving the problem. Design specifications describe your goals for the product. They describe the characteristics the product must have to solve the problem. The design specifications for the business card problem might include the following:

* The device should encourage people to take a business card.
* The device should display the cards so they can be easily read while standing in front of a sales counter or sitting in front of a desk.
* The device should allow customers to take one card without disrupting the rest of the cards in the holder.
* The device should be pleasant to look at and should fit in with other desktop organizing devices.

The last step in understanding a problem is to identify the limitations that must be taken into account when solving the problem. It would be a waste of time to design a plastic product if the manufacturer is only equipped to process wood and metal. You would not want to design a product that will cost a million dollars to make if you can only afford to invest ten thousand dollars. The six basic types of limitations are:

* human resources
* material resources
* facility limitations
* time limitations
* information resources
* financial resources

The limitations for a student enterprise addressing the business card problem might include the following:

* We can manufacture the device out of wood or plastic.
* We must be able to manufacture the device using simple woodworking tools and machines.
* We can involve up to fifteen people in the manufacturing process.
* We only have two weeks to manufacture the device.
* The device should not have more than four parts.

* We can raise approximately $50 to finance the project.
* We want to make as big a profit as possible.

The people in research and development develop new products to solve the problems we face today. The first step in solving a problem is to define it accurately and analyze it. Before we can solve a problem, we must be able to define it clearly, list the specifications for its solution, and list our limitations.

Learning Activity:

Directions: The first step in the research and development process is to observe a situation and identify a problem or an opportunity to make improvements. Your teacher will set up a situation that includes a variety of problems. Your design team needs to study the situation and identify a specific problem that can be solved with a new product. Once you have identified a problem, your team needs to define it accurately. In the space provided, write a problem statement that describes the problem you would like to solve with a new product.

_____

_____

_____

Directions: Once you have defined the problem accurately, your design team needs to list the specifications for the solution. You are basically answering the question, what must the product do? In the space provided, list the specification for the solution to your problem.

The device must:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____

Directions: Next, your design team needs to list the limitations that must be taken into account when trying to solve the problem. Discuss each of the following questions. Circle the items that best describe your problem-solving limitations. You may need to circle more than one item. Feel free to write in your own answers if the ones provided are not appropriate.

1. What kinds of materials are available in your laboratory?

   a. wood
   b. metal
   c. plastic
   d. paper
   e. ceramics
   f. leather
   g. other _____

2. The budget for manufacturing the product will be about ____ dollars.

   a. 20
   b. 30
   c. 40
   d. 50
   e. other _____

3. How many units can you produce and sell?

   a. 10-25
   b. 25-50
   c. 50-100
   d. 100-150
   e. other _____

4. Who will you be selling your product to?

   a. students
   b. teachers
   c. parents
   d. the general public
   e. other _____

5. How much time is available to manufacture the product?

   a. 1 week
   b. 2 weeks
   c. 3 weeks
   d. 4 weeks
   e. other _____

6. How many students need to be involved in the manufacturing process?

   a. 10-15
   b. 15-20
   c. 20-25
   d. 25-30
   e. other _____

7. What kinds of tools and machines can be used during the manufacturing process?

   a. woodworking hand tools
   b. metalworking hand tools
   c. hand tools for plastic
   d. leatherworking hand tools
   e. hand tools for ceramics
   f. portable electric drills
   g. portable electric saber saws
   h. portable electric sanders
   i. miter box saw
   j. band saw
   k. table saw
   l. jointer
   m. planer
   n. router
   o. disk/belt sander
   p. lathe (woodworking and/or metalworking)
   q. drill press
   r. sheet metal equipment
   s. plastic forming equipment
   t. other _____

Unit: Research and Development — Lesson 2 Gathering Information

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify a definition for research -describe the two basic types of research. -list the four basic techniques used to gather information. -list the five basic steps in the research process	A. Gathering information 1. Research is a systematic process for discovering and gathering information. 2. Types of research a. pure b. applied 3. Basic steps for research project. a. state the problem b. identify research questions c. design the research activity d. collect the information e. report the results 4. Basic techniques for gathering information a. review literature b. conduct surveys c. conduct experiments d. consult experts 5. Information sources a. industry b. specialists c. libraries d. government agencies e. trade magazines f. consumers	A. Teacher Guided Discussion 1. Ask students if they have all the information they need to solve their problems. Discuss the importance of gathering information when solving a problem 2. Using OT #2-1, discuss the definition of research. 3. Using OT #2-2, discuss the difference between pure and applied research. 4. Discuss the roll of research questions during the information gathering process. 5. Using OT #2-3, discuss the four basic techniques used to gather information. 6. Using OT #2-4, discuss possible sources for information.	TA #2-1: Gathering Information OT #2-1: Definition of Research OT #2-2: Pure and Applied Research OT #2-3: Techniques for Gathering Information OT #2-4: Sources for Information

B. Following a demonstration in a lab activity, students will be able to: -write a series of research questions based on their problem statement. -develop a research activity for answering each research question. -answer each research question based on the information collected.	B. Researching a problem 1. Write a problem statement. 2. Write a list of research questions. 3. Design a research activity for each question. 4. Research each question. 5. Analyze the information collected. 6. Answer each research question.	B. Learning Activity 1. Using an example problem statement, demonstrate how to write a list of research questions. 2. Ask students to identify the best research method for each research question. 3. Discuss how to design a research activity for each question. 4. Demonstrate how to consult an expert, review literature, conduct a survey, and conduct an experiment. 5. Provide each student with HO #2-1 and have them get into their research and development teams. 6. Have each team begin researching their problem. 7. Circulate around the room and provide individual instruction as needed. 8. Check each team's plans for answering their research questions prior to implementation. 9. When students have completed the lab activity, collect and evaluate each team's research project.	HO #2-1: Gathering Information

GATHERING INFORMATION

Preparation Hints:

1. Review the materials provided, duplicate HO #2-1, and prepare the transparencies needed to present the lesson.

2. During this lesson, your students will need access to a variety of reference materials. Consider taking your students to the library for one class period. Prior to using the library, introduce your school librarian to the research project and discuss how your students should use the library to gather information.

3. In the interest of time, gather a variety of reference materials not often found in the library. For example, your students may need to look through hardware, electronics, and/or office supply catalogs.

4. Prior to implementing this lesson, consider preparing materials for demonstrations on contacting experts in industry, conducting surveys and conducting experiments.

Content Presentation Hints:

1. Describe a variety of research activities that are commonly conducted in industry. For example, tensile testing steel, subjecting paint to the sun, and crash testing cars. Ask students to identify which research activities are pure research and which are applied research.

2. Write a sample problem statement on the chalkboard. Ask your students to identify the kinds of information needed to solve the problem. Using your students ideas, develop a set of research questions.

3. Ask students to identify possible research methods and information sources for each research question.

4. Consider inviting a guest speaker from industry to visit your class to discuss how their company conducts research.

Learning Activity Hints:

1. Using the business card example listed in HO #2-1, or similar problem, explain how to research a problem.

2. The primary objective of this lesson is to introduce students to the research process. In the interest of time and insuring success, encourage students to keep their research activities simple.

3. Provide each team an extra copy of HO #2-1 that can be collected and evaluated at the end of the lesson. Ask students to use their individual copies for rough drafts of their research project.

4. To save time, encourage teams to divide the work among the team members. For example, each team member could address two research questions. Another option would be to ask one team member to conduct surveys, another team member to conduct an experiment, and another team member to review literature.

5. Demonstrate the proper procedures for consulting experts in industry and conducting surveys. Emphasize the importance of introducing yourself, explaining the purpose of the project, and stating questions clearly. Ask students to practice their research skills with team members. You may want to consider approving all research instruments before they are implemented (i.e., letters of inquiry, surveys, questions, experiments).

OT #2-1

Definition of Research:

Research is a systematic process for discovering and gathering information.

OT #2-2

PURE RESEARCH

is gathering information to learn more about a subject.

APPLIED RESEARCH

is gathering information to solve a specific problem.

OT #2-3

Basic techniques for gathering information:

* review literature
* conduct surveys
* conduct experiments
* consult experts

OT #2-4

Possible sources for information:

* specialists
* libraries
* government agencies
* trade magazines
* consumers
* industry

GATHERING INFORMATION

Discussion:

Once a problem has been identified and accurately defined, it needs to be researched. Research is a systematic process for discovering and gathering information to solve the problem.

There are two basic types of research, pure research and applied research. Pure research is basically gathering information to learn more about a given subject. Learning how far you can bend various materials before they will break is an example of pure research.

Applied research is basically gathering information that will help solve a specific problem. Testing the strength of various materials to build a light weight bicycle frame is an example of applied research.

The next step in the process is to make a list of research questions. Research questions identify what you need to know to solve the problem. A set of research questions for the business card problem might include the following:

1. How many cards should be displayed at a time?

2. How big are most business cards?

3. What do the business card holders on the market look like?

4. How much do the business card holders on the market cost?

5. Should business cards be displayed horizontally or vertically?

6. What kinds of materials are used to make most desktop organizing devices?

Research questions can be answered by asking experts, reviewing reference materials, conducting surveys, or conducting experiments. Which method is best depends on the question. To learn the dimensions for standard business cards, you could ask a professional printer. Experts in industry can be contacted in person, by phone, or by writing a letter. When you ask experts for help, it is important to introduce yourself, to explain what you are doing, and to state your questions clearly.

To learn how many business cards should be displayed, you could survey local merchants. During the survey you could ask them how many business cards they give out each week. A survey is basically a list of questions and a checklist of possible answers. When you conduct a survey, it is very important to introduce yourself, to explain what you are doing, and to ask your questions clearly.

To learn about the business card holders currently on the market, you could review a variety of office supply catalogs. During the review you could determine what business card holders look like and how much they cost. In addition, you could identify the materials used to make desktop organizers (i.e., pen holders, book ends, memo pad holders, etc.). A good place to begin for a review of literature is your school library.

To learn whether business cards should be displayed vertically or horizontally, you could conduct an experiment. In the experiment, you could display two business card holders, one vertical and one horizontal, and ask people to take a business card. The business card holder people pick from the most would be the best design. When you conduct an experiment, it is important to consider the factors that can effect the results. For example, people might pick business cards from one holder because it is on the right versus the left. Or, they may pick from the one that has the fewest cards in it. It is important to think ahead and control as many factors as possible when conducting an experiment.

The last step in the research process is to report the information you have collected. During this step, you need to answer your original research questions.

The people in research and development conduct research to discover and gather information. To gather information, a researcher can consult experts, review reference materials, conduct surveys, and conduct experiments. When researching a problem, you need to state the problem, make a list of research questions, design the research activity, collect the information, and report your results.

Directions: The first step in researching your problem is to state the problem. Write your problem statement in the space below.

Research Project Problem Statement

_____

_____

Directions: The next step is to identify the information needed to solve the problem. You can do this by asking yourself: What do I need to know? Analyze your problem statement and write a list of research questions in the space below.

Research Questions

1. _____

_____

2. _____

_____

3. _____

_____

4. _____

_____

5. _____

_____

6. _____

_____

Directions: The next step is to identify how you are going to answer each research question. You can answer questions by asking experts, reviewing reference materials, conducting a survey, and/or conducting an experiment. Which method you use depends on the question. One method may work for one question but not another. Analyze each question carefully and write how you are going to obtain the information you need.

Methodology

Question No. 1: _____

_____

_____

Question No. 2: _____

_____

_____

Question No. 3: _____

_____

_____

Question No. 4: _____

_____

_____

Question No. 5: _____

_____

_____

Question No. 6: _____

_____

_____

Directions: The next step in the process is to collect the information you need to solve your problem. When you have finished gathering information, use the space provided to answer each research question.

Final Report

Question No. 1: _____

_____

Question No. 2: _____

Question No. 3: _____

Question No. 4: _____

Question No. 5: _____

Question No. 6: _____

Unit: Research and Development

Lesson 3: Developing Preliminary Designs

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify a definition for development. -explain how the visualization technique is used to develop preliminary designs. -describe the characteristics and functions of a thumbnail sketch. -explain how the brainstorming technique can be used to generate ideas.	A. Developing Preliminary Designs 1. Development is using information to design a solution to a problem. 2. Visualization is the ability to: a. think using mental pictures b. use mental pictures to draw visible pictures 3. Characteristics of a thumbnail sketch a. drawn quickly b. very rough c. very little detail 4. Functions of a thumbnail sketch a. visualize an idea b. store an idea c. communicate an idea 5. Brainstorming a. generate ideas freely b. record all ideas c. do not evaluate ideas	A. Teacher Guided Discussion 1. Ask students what they think is the next step in creating a new product. Using OT #3-1, discuss the definition of development 2. Discuss the concept of developing preliminary designs. 3. Using OT #3-2, discuss how visualization can be used to develop preliminary designs. 4. Using OT #3-3, discuss how thumbnail sketches are used during the visualization process. 5. Using OT #3-4, discuss how the brainstorming technique can be used to generate design ideas. 6. Explain why it is important not to evaluate ideas during the brainstorming process. 7. Discuss the importance of team work during the brainstorming process.	TA #3-1: Developing Preliminary Designs CT #3-1: Definition of development CT #3-2: Visualization OT #3-3: How to Use Thumbnail Sketches OT #3-4: Brainstorming

B. Following a demonstration in a lab activity, students will be able to: -use the visualization and/or brainstorming technique to generate a variety of preliminary design ideas. -record their preliminary design ideas in the form of thumbnail sketches.	D. Developing Preliminary Designs 1. Review a. problem statement b. design specifications c. research information 2. Generate preliminary design ideas a. visualization b. brainstorming 3. Record preliminary design ideas using thumbnail sketches.	B. Learning Activities 1. Conduct a visualization exercise by asking students to draw a familiar object with their eyes closed. 2. Demonstrate on the chalkboard how to draw a thumbnail sketch. 3. Using an example problem statement and a few students from the class, conduct a mock brainstorming session. 4. Provide each student HO#3-1, and several pieces of graph paper. 5. Have the students get into their design teams and begin developing preliminary designs. 6. Circulate around the room and provide individual instruction as needed. 7. Recognize and encourage teamwork and creativity. 8. Before the end of the period, provide students with feedback regarding their preliminary designs. 9. Collect and evaluate each team's thumbnail sketches.	HO #3-1: Developing Preliminary Designs

DEVELOPING PRELIMINARY DESIGNS

Preparation Hints:

1. Review the materials provided, duplicate HO #3-1, and prepare the transparencies needed to present this lesson.

2. Prior to implementing this lesson, you may want to locate and review a variety of reference materials on design and using the brainstorming technique.

3. During the lab activity, your students will need graph paper for their thumbnail sketches. To encourage teamwork, you may want to consider purchasing graph paper in large sheets. A second option would be to tape several individual sheets into one large sheet. Providing each student with an individual sheet of graph paper will discourage teamwork.

4. Consider obtaining and showing a videotape or film on creative thinking, design, or brainstorming.

5. Consider asking a local design or architectural firm for a few examples of thumbnail sketches.

Content Presentation Hints:

1. Ask a designer or an architect to visit your class and present how they develop preliminary designs for a project.

2. Ask your students to identify some products that may have been based originally on silly ideas, but proved to be very useful solutions to life's little problems. For example, your discussion could include things like weed eaters, suspenders, and air bags in cars.

Learning Activity Hints:

1. To help students understand and experience the visualization concept, conduct a little exercise. Ask students to take out a piece of paper and a pencil. Ask your students to look at a simple and familiar object, such as a chalkboard eraser. Next, tell your students to imagine the object on the piece of paper. Have your students close their eyes and draw the object on the paper. For the best results, tell your students to leave their pencil on the paper at all times. If time permits, repeat the exercise with progressively more difficult objects.

2. Using the business card example, demonstrate on the chalkboard how to draw a thumbnail sketch. You may need to discuss and demonstrate various sketching techniques if your students have not been exposed to sketching before. During the demonstration, stress the importance of drawing thumbnails quickly and without a lot of detail.

3. Using the business card example, conduct a mock brainstorming session. Ask several students from the class to come to the chalkboard and provide each with a piece of chalk. Give the team about two minutes to develop as many preliminary designs as possible. When the two minutes are up, discuss how successful the students were using the brainstorming technique, and make a few recommendations for future brainstorming sessions.

Development is using information to design a solution to a problem.

OT #3-2

Visualization is the ability to:

* think using mental pictures
* use mental pictures to draw visible pictures

OT #3-3

Functions of a thumbnail sketch are:

* select best ideas
* store an idea
* communicate an idea

OT #3-4

Brainstorming

* generate ideas freely
* records all ideas
* does not evaluate ideas

DEVELOPING PRELIMINARY DESIGNS

Discussion:

During the research process, the goal is to gather the information needed to solve a problem. During the development process, the goal is to use the information gathered to design a solution to the problem. The first step in the development process is to create a variety of possible solutions to the problem. These solutions are called preliminary designs. Designers use two creative thinking techniques to help them create preliminary designs, visualization, and brainstorming.

Visualization is the ability to think using mental pictures. Designers use their imaginations to create new products. The first step in the visualization process is to create a clear mental picture of an idea. The next step is to use the mental picture to draw a visable picture on paper.

Designers use thumbnail sketches to record their ideas. Thumbnail sketches are drawn quickly and very rough (see Figure 3-1). Detail is not important during this stage of the development process. If an idea has promise, a detailed drawing can be made later.

Thumbnail sketches play several important roles during the visualization process. First, they help the designer visualize their ideas and create more ideas. Second, they allow the designer to store their ideas so they can visualize a new idea. Lastly, they help the designer communicate their ideas to others.

The goal of brainstorming is to think freely and generate as many ideas as possible. Quantity is more important than quality. During the brainstorming process, it is important to encourage creative thinking. Therefore, no one is allowed to judge ideas as they are being born. Every idea is given a chance and every idea is recorded, even if they seem silly at the time. Sometime, silly ideas prove to be the best ideas or they lead to better ideas.

Brainstorming is typically a team effort. All the members of the team need to feel they can contribute ideas without fear of criticism. If one member's ideas are called silly or stupid, they may stop contributing ideas and the best idea may never be discovered.

Using information to create a new product is called development. The first step in the development process is to create a variety of preliminary designs. Designers use visualization and brainstorming techniques to create preliminary designs. Designers record their ideas by drawing simple sketches called thumbnails.

Directions: In your design teams, review your problem statement, design specification, and research information. Use the visualization and/or brainstorming techniques to create as many preliminary designs as possible. Draw a thumbnail sketch for each design idea on graph paper. Keep your sketches small and simple. Do not worry about neatness and accuracy. Do not evaluate your ideas. Concentrate on creating and recording.

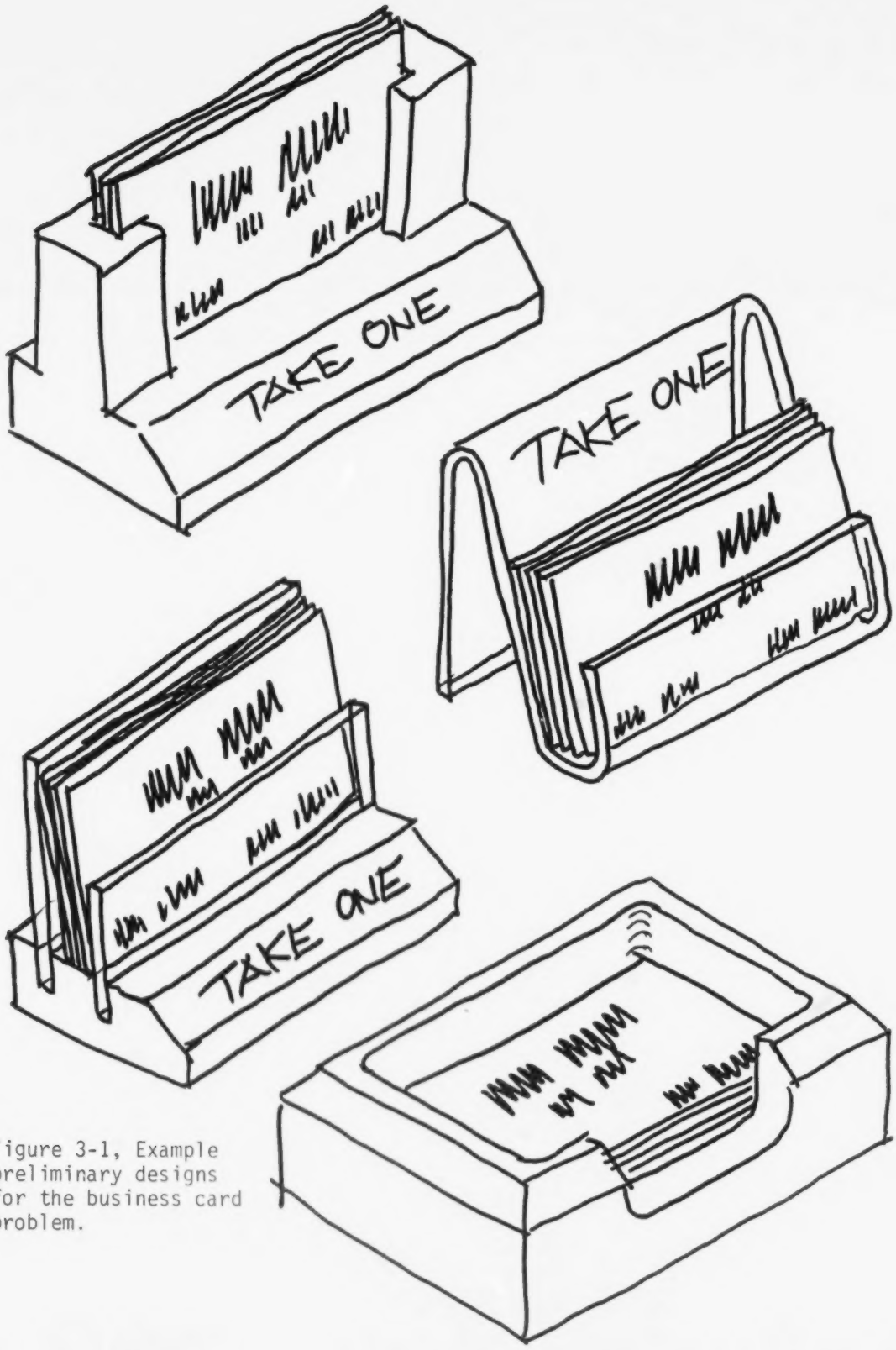


Figure 3-1, Example preliminary designs for the business card problem.

Unit: Research and Development

Lesson 4: Selecting and Refining a Design

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -list the eight basic design considerations used to evaluate preliminary designs. -describe how to refine a design through drawings -describe how to refine a design through mock-ups. -distinguish the difference between paste-up, appearance and hard mock-ups.	A. Selecting and Refining a design. 1. Basic design considerations. a. function b. appearance c. safety d. ease of servicing e. market appeal f. cost g. ease of manufacturing h. durability 2. Refining design ideas through drawings a. rough sketches b. rendering 3. Refining design ideas through mock-ups a. paste-up mock-ups b. appearance mock-ups c. hard mock-ups	A. Teacher Guided Discussion 1. Ask students how they plan to identify the best design among their preliminary designs. 2. Using OT #4-1, discuss the eight basic design considerations used to evaluate preliminary designs. 3. Explain how each design consideration can be put into the form of a question. Explain how the questions can be used to evaluate preliminary designs. 4. Explain how the evaluation process is used to identify the best design. 5. Using OT #4-2, discuss how designs can be refined through drawings. 6. Discuss the characteristics of a rough sketch and a rendering. 7. Using OT #4-4, discuss how designs can be refined through mock-ups. 8. Discuss the characteristics of the three basic types of mockups.	TA #4-1: Evaluating and Refining a Design OT #4-1: Design Considerations OT #4-2: Refining Design Ideas OT #4-4: Refining Design Ideas

B. Following a demonstration in a lab activity, students will be able to: -evaluate their preliminary designs using the eight basic design considerations. -identify and/or develop the best design from among the preliminary design ideas. -refine their design by developing a final sketch -refine their design by developing a mock-up.	B. Selecting and Refining a design 1. Evaluating preliminary designs. 2. Identifying and/or developing a final 3. Drawing final sketch 4. Making a mock-up	B. Learning Activity 1. Using OT #4-3, demonstrate how to evaluate a preliminary design using eight basic design considerations. 2. Demonstrate how to develop a final sketch on the chalkboard. 3. Using the final sketch as a guide, demonstrate how to use the tools and materials available to make a mock-up. 4. Provide each student with HO #4-1 and return their thumbnail sketches. 5. Have the students get into their design teams and begin evaluating their preliminary designs. 6. Circulate around the room and provide individual instruction as needed. 7. When students have completed the evaluation process, provide each team a piece of graph paper for their final sketch.	OT #4-3: Drawing HO #4-1: Evaluating and Refining a Design

8. When students have completed their final sketch, provide them with the tools and materials to develop a mock-up.
9. Recognize and encourage team work and creativity.
10. Collect and evaluate each team's preliminary designs, final sketch, and mock-up.

SELECTING AND REFINING A DESIGN

Preparation Hints:

1. Review the materials provided, duplicate HO #4-1, and prepare the transparencies needed to present this lesson.

2. During the lab activity, your students will be building mock-ups. Prior to implementing this lesson, you will need to collect a variety of easy to work materials. You will want to include things like wood, paper, cardboard, foam core, styrofoam, clay, plastic, tape, glue, and straight pins.

3. During the lab activity, your students will be developing a final sketch of their design. To enable students to make their drawings look like renderings, you may want to consider providing a variety of colored pencils and/or magic markers.

4. Consider developing a variety of example renderings and mock-ups. Developing examples will help you anticipate problems, identify appropriate materials, and develop strategies for ensuring student success.

Content Presentation Hints:

1. When discussing design considerations, ask students to identify products that do not work, are unpleasant to look at, are not safe to use, are difficult to maintain, are difficult to sell, cost too much, and difficult to manufacture.

2. To help students understand the advantages of a three dimensional model over a two dimensional rendering, show students a picture of an object and compare it to a model or to a real thing. For example, you could ask students to compare an automobile poster to a model of the same automobile.

Learning Activity Hints:

1. Using the business card example, demonstrate on a chalkboard how to draw a final sketch. You may need to review various sketching techniques. In addition, you may want to demonstrate how to add details like wood grain and shading to make the sketch look more like a rendering. During your demonstration, be sure students

understand that it will take time for their sketch to evolve from a rough idea on paper to a very lifelike drawing.

2. Using the business card example, demonstrate how to use the tools and materials available to make a mock-up. Stress the importance of safety when using saws, razer knives, adhesives, and power tools. In addition, you may want to provide students with pieces of hardboard to protect the table tops when they are cutting and glueing materials.

Basic design considerations:

* function
* appearance
* safety
* ease of servicing
* market appeal
* cost
* ease of manufacturing
* durability

OT #4-2

Refining design ideas through drawings:

* rough sketches
* renderings

OT #4-4

Refining design ideas through mock-ups:

* paste-up mock-ups
* appearance mock-ups
* hard mock-ups

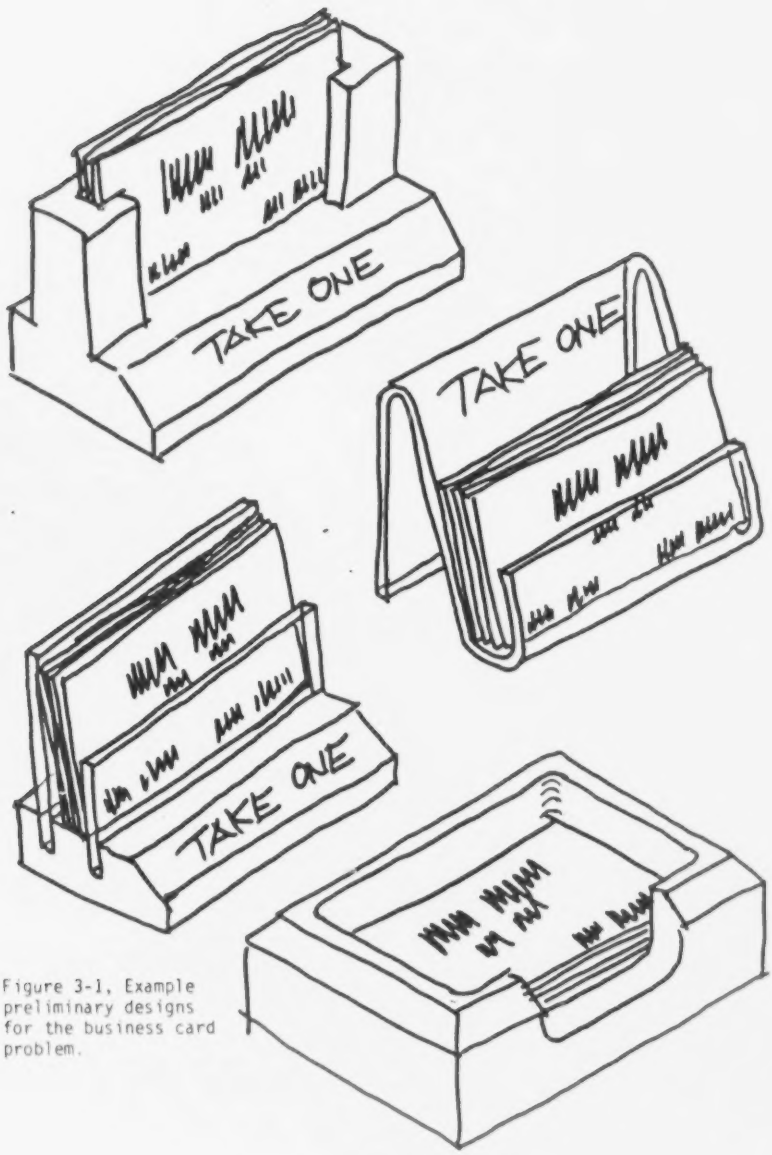


Figure 3-1, Example preliminary designs for the business card problem.

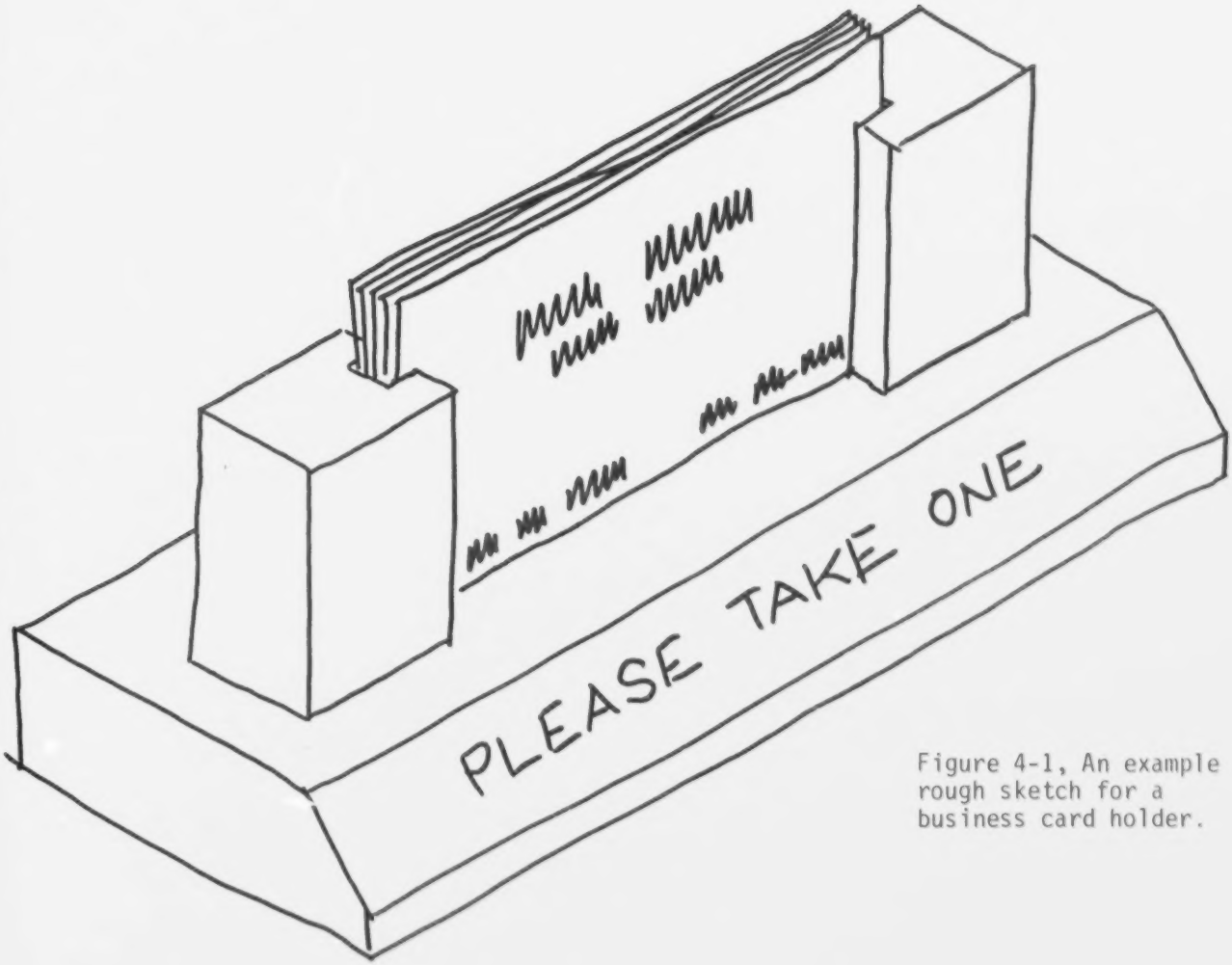


Figure 4-1, An example rough sketch for a business card holder.

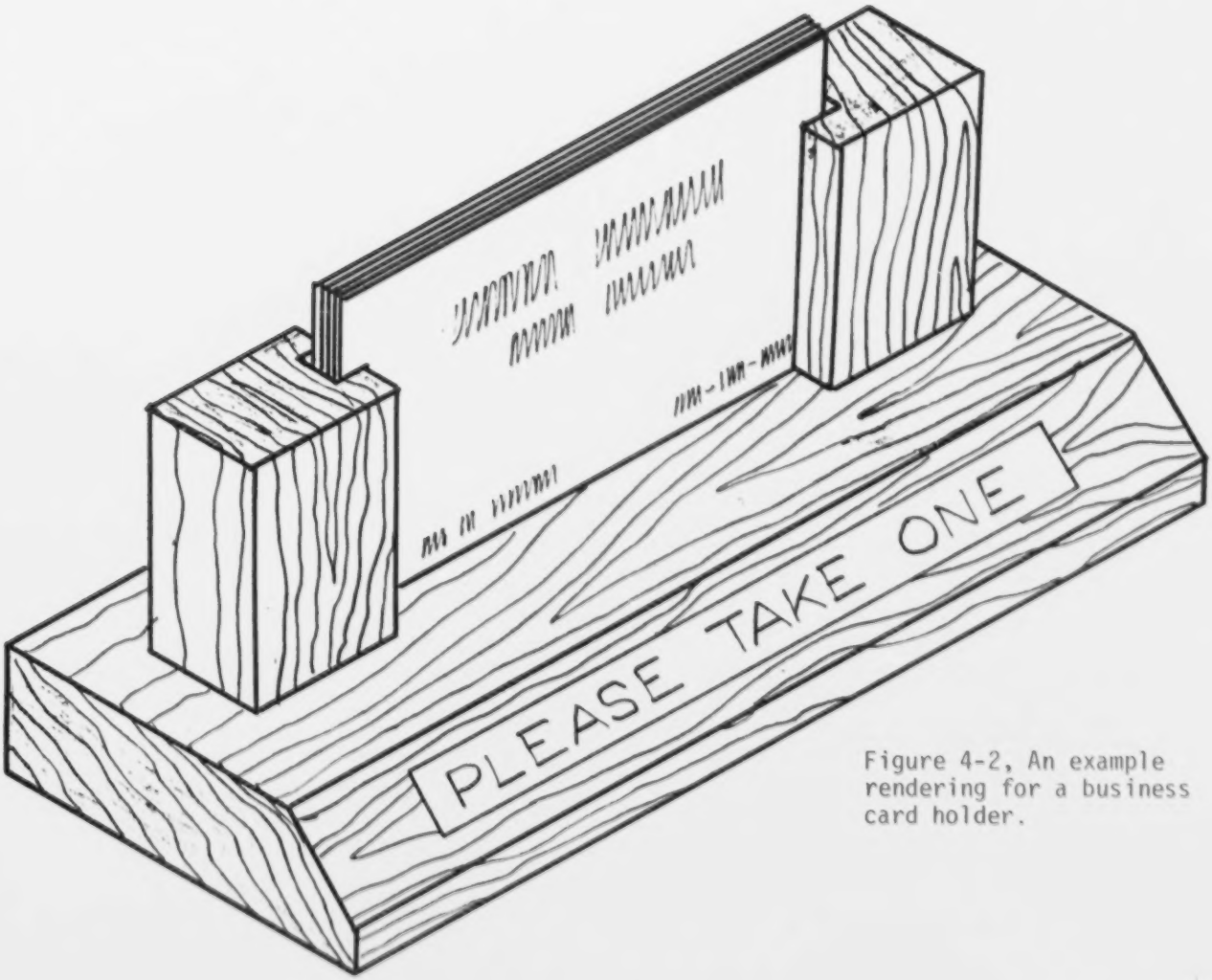


Figure 4-2, An example rendering for a business card holder.

SELECTING AND REFINING A DESIGN

Discussion:

The problem-solving process has several stages. You have already identified a problem, gathered information about the problem, and developed a variety of preliminary designs. The next step is to evaluate each preliminary design.

The purpose of the evaluation process is to identify the best design. To identify the best design, designers use a list of design considerations to evaluate each preliminary design. A typical list of design considerations might include things like:

* function
* appearance
* safety
* ease of servicing
* market appeal
* cost
* ease of manufacturing
* durability

During the evaluation process, each design consideration can be put into the form of a question. Together, all the questions make a test. The following test questions could be used to evaluate the preliminary designs for the business card holder problem.

1. Will the design do what it is suppose to do?
2. Is the design pleasant to look at?
3. How much will it cost to manufacture the design?
4. Is the design safe to manufacture and use?
5. Can the design be serviced easily?
6. Will people purchase the design?
7. How hard will it be to manufacture the design?
8. How long will the design last.

At the end of the evaluation process, one preliminary design might prove to be the best. Or, a combination of ideas from several preliminary designs might be combined to make the best design.

Once the best design has been identified, it needs to be refined (improved). Designers refine designs by making detailed drawings and/or models. They help the designer discover what the final product will look like and how it can be made.

To refine a design through drawings, a designer must first draw a rough sketch. A rough sketch is larger and includes more detail than a thumbnail sketch. After drawing a rough sketch, the designer is ready to develop a rendering. A rendering is a very lifelike picture of the design. Sometimes, they are so lifelike they look like photographs. They include a lot of detail and they are often drawn in color. Since they are so lifelike, rendering can be used to ask consumers what they think of the new product before the first one is even made.

A drawing can provide only a two dimensional representation of a design. The primary advantage of a model is that it can represent a design in three dimensions. You can pick up a model and look at its front, top, back, bottom, and sides. The models made during the development process are called mock-ups. There are three basic types of mock-ups. The simplest is called a paste-up mock-up. They are typically made out of easy to work materials like paper, cardboard, clay, wood, or styrofoam. Paste-up mock-ups allow the designer to see what the product will basically look like without spending a lot of time and money.

Appearance mock-ups are models that look like the real thing. They are typically full size. However, they usually do not have any working parts. They can be made out of any material that can create the lifelike appearance. An appearance mock-up of a stereo would look real from a distance. However, up close, you would most likely discover the controls do not work. If you pick it up, you might discover it is nothing more than a hollow plaster shell. The materials commonly used to make appearance mock-ups include wood, plastic, and clay.

The most realistic and detailed models are called hard mock-ups. For all practical purposes, hard mock-ups look and work like the real thing. However, they do not include the internal parts that would allow the product to work. They are typically made out of the materials that will be used to make the final product. A hard mock-up of a stereo might include working knobs and switches. It may even have a tape door that opens and closes. However, it would not include the electronics that would enable you to tune in a radio station or play a cassette tape.

The first step in the development process is to develop a variety of preliminary designs. A list of design considerations are used to evaluate each design and identify the best design. Once the best designs have been identified, the design is refined through rough sketches, renderings, and/or mock-ups. During the refinement process, the design evolves from a rough idea sketch on paper to a very lifelike drawing and/or model.

Learning Activity:

Directions:

1. In your design teams, use the questions listed below to discuss and evaluate each of your preliminary designs. Try to find good ideas in each design. During the evaluation process, write notes near each sketch that identify good ideas and possible problems.

   - Will the design do what it is suppose to do?
   - Is the design pleasant to look at?
   - How much will it cost to manufacture the design?
   - Is the design safe to manufacture and use?
   - Can the design be serviced easily?
   - Will people purchase the design?
   - How hard will it be to manufacture the design?
   - How long will the design last?

2. When you have finished evaluating each design, review your notes and select the best design. You may find one idea is clearly the best. However, you may need to combine good ideas from several designs to create the best design. Make sure your best design meets all the design considerations.

3. After you have identified the best design, it needs to be refined. The first step in the refinement process is to develop a final sketch. Your final sketch should be larger and include more detail than your thumbnail sketches. Try to improve your design as you draw. Do not be afraid to make changes.

4. Using your final sketch as a guide, use the materials provided by your teacher to make a mock-up of your design. Make sure you protect the table top when you are cutting and glueing materials. Try to make your mock-up the same size as the final product.

Unit: Research and Development

Lesson 5: Specifying the Design

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify the goal of product engineering. -explain the purpose of specifying a product design. -describe the communication tools used to specify a product design.	A. Specifying the design 1. The goal of product engineering is to prepare the design for manufacturing 2. Specifying the design includes: a. describing parts b. defining size and shape c. identifying materials d. describing assembly 3. Purposes of specifying the design: a. determine how to make the product b. test the design c. communicate the design 4. Communication tools a. detailed drawings b. assembly drawings c. schematic drawings d. bill of materials e. notes and specifications	A. Teacher Guided Discussion 1. Using OT #5-1, review the goal of research and development. Introduce students to the goal of product engineering. 2. Using OT #5-2, discuss the basic elements address during the design specification process. 3. Using OT #5-3, discuss the basic purposes of specifying a product design. 4. Using OT #5-4 through 5-9, discuss the various communication tools used to specify a product design.	TA #5-1: Specifying the Design OT #5-1: Goals OT #5-2: Specifying the Design OT #5-3: Purposes of Specifying OT #5-4: Communication Tools OT #5-5 through OT #5-9: Drawings

B. Following a demonstration in a lab activity, students will be able to:
-develop a set of plans for their product design.
-complete bill of materials for their product design.
-complete a specification sheet for their product design.

B. Specifying the design
1. Drawing a set of plans
   a. detailed drawings
   b. assembly drawings
   c. schematic drawings
2. Completing a bill of materials.
   a. part number
   b. part name
   c. material
   d. dimensions
   e. quantity
3. Completing a specification sheet.

B. Learning Activity
1. Using an example mock-up, demonstrate how to draw a set of plans on the chalkboard. Review the concept of orthographic projection if necessary.
2. Using an example mock-up, explain how to complete a bill of materials and a specification sheet.
3. Provide each student with HO #5-1 and return their final sketches and mock-up. Provide each team with several sheets of graph paper.
4. Have students get into their design teams and begin specifying their product designs.
5. Encourage students to divide the work among the members of their design teams.
6. Circulate around the room and provide individual instruction as needed.
7. Before the end of the period, provide each team feedback regarding their plans, bill of materials, and specification sheet.
8. Collect and evaluate each teams' plans, bill of materials, and specification sheets.

HO #5-1: Specifying the Design

SPECIFYING THE DESIGN

Preparation Hints:

1. Review the materials provided, duplicate HO #5-1, and prepare the transparencies needed to present this lesson.

2. Collect as many examples of working drawings, bills of materials, and specification sheets as possible. Display the example so your students can refer to them for information regarding things like format, dimensioning, notes, title block documentation, and specifications.

3. During this lesson, your students will need to develop a set of working drawings for their product. This lesson offers an excellent opportunity to integrate computer-aided-drafting (CAD) into the curriculum. If you are already equipped for CAD, plan an introductory lesson that will enable your students to develop a simple set of working drawings for their product. If you are not equipped for CAD, investigate your access to the school's microcomputers and preview a variety of low cost CAD software on the mar-ket. Prior to implementing this lesson, purchase and learn how to use a software package that will meet your needs.

4. If you are not going to use CAD, your students will need graph paper, rulers, erasers, and pencils.

5. If your students have not been introduced to drafting, you will need to prepare short lessons on orthographic projection, dimensioning, and documenting a drawing.

Content Presentation Hints:

1. When introducing the need to specify a design, show the class a rendering and/or a mock-up. Ask them if they know what materials should be used to make the product. Also ask them if they know the dimensions for each part. Discuss the need to develop a set of plans for the product.

2. Consider showing a film or video tape on computer-aided-drafting or computer-aided-design.

3. Show students a variety of examples when discussing detailed drawings, assembly drawings, schematic drawings, bills of material, and notes and specifications. After presenting the lesson, display the example drawings throughout your laboratory.

Learning Activity Hints:

1. Using an example rendering and/or mock-up, discuss how to divide the product up into individual parts. Discuss how no one engineer is responsible for drawing the plans for a whole automobile. Discuss how individual parts are assigned to a variety of engineers. Together, their drawings make a set of working drawings for the product. Explain how each design team will need to divide their product into individual parts and assign a part to each team member.

2. Demonstrate on the chalkboard how to draw a simple multi-view drawing. When the drawing is complete, demonstrate how to add dimensions to the object.

3. Using an example mock-up as a guide, demonstrate on the chalkboard how to complete a bill of materials for a product. During your demonstration, give each part a number, a name, describe its dimensions, identify the material used, and list the quantity needed.

4. Demonstrate how to use a specification sheet to provide information that cannot be drawn. During your demonstration, create a specification that describes what adhesive to use for a specific assembly. Your specification should include what type of adhesive to use, how to apply the adhesive and the drying time for the adhesive.

GOALS

RESEARCH: To gather the information needed to solve a problem.

DEVELOPMENT: To design a product that will solve the problem.

PRODUCT ENGINEERING: To prepare the design for manufacturing.

OT #5-2

Specifying the design includes:

* describing parts
* defining size and shape
* identifying materials
* describing assembly

OT #5-3

Purposes of specifying the design:

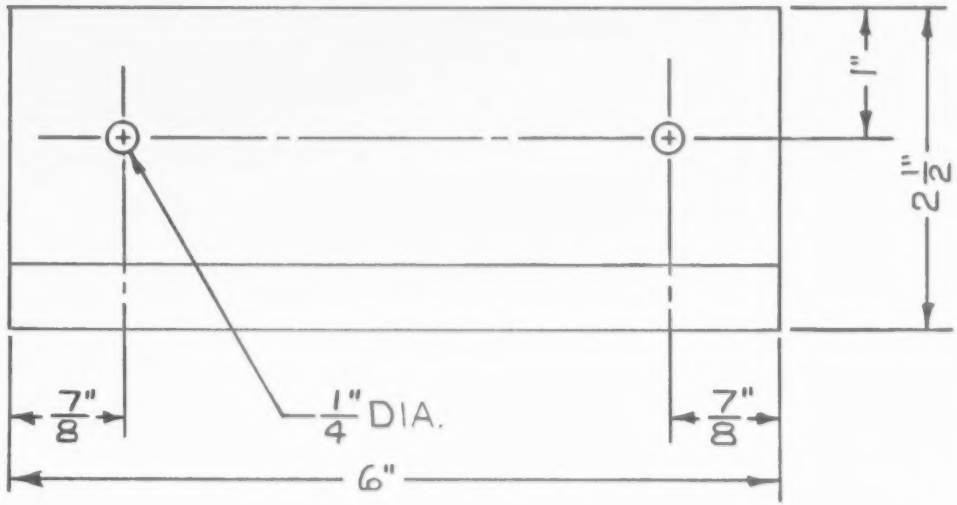
* determine how to make the product
* test the design
* communicate the design

OT #5-4

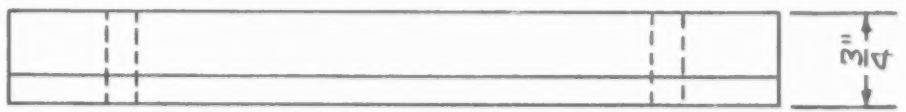
Communication tools:

* detailed drawings
* assembly drawings
* schematic drawings
* bill of materials
* notes and specifications

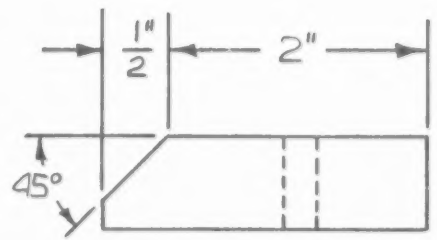
TOP VIEW



SCALE: 3/4" = 1"



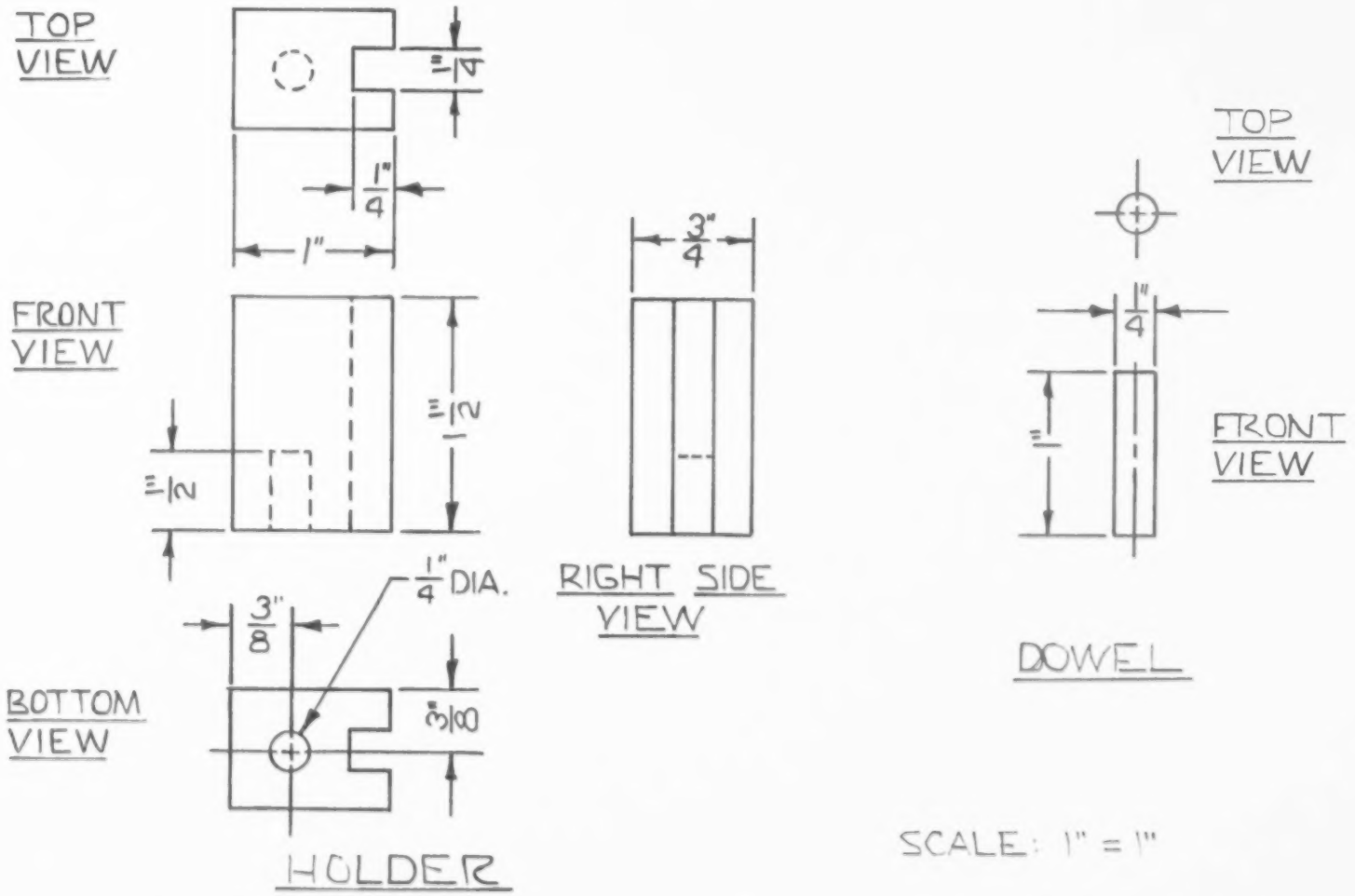
FRONT VIEW



RIGHT SIDE VIEW

NAME: JOHN SMITH	BUSINESS CARD HOLDER	PART: BASE	DATE:

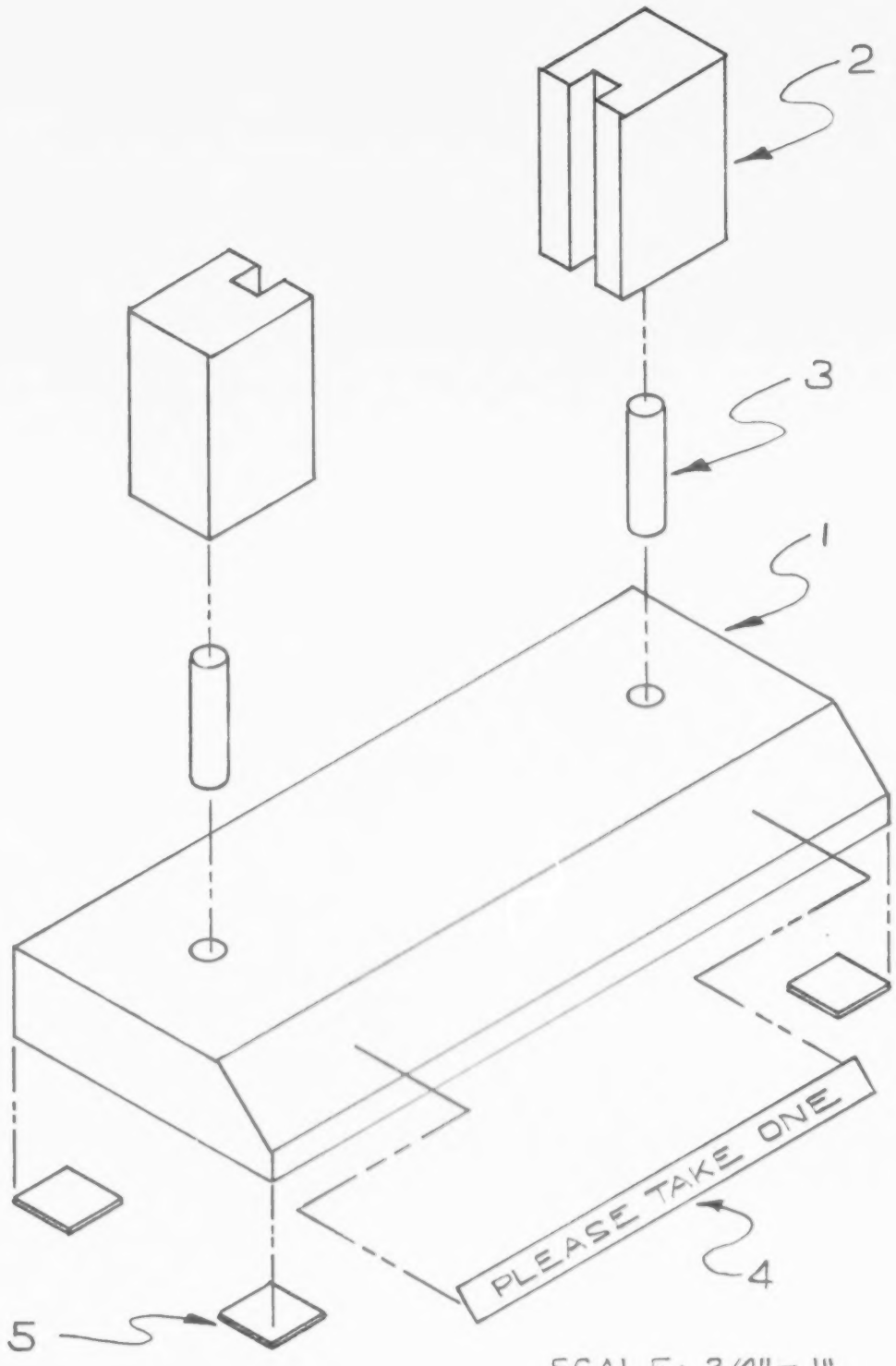
OT #5-5



SCALE: 1" = 1"

NAME: JOHN SMITH	BUSINESS CARD HOLDER	PART: HOLDER + DOWEL	DATE:

OT #5-6



SCALE: 3/4" = 1"

NAME: JOHN SMITH	BUSINESS CARD HOLDER	ASSEMBLY

BILL OF MATERIALS				
PART NUMBER	PART NAME	MATERIAL	DIMENSIONS L×W×D	QUANTITY
1	BASE	MAHOGANY	6" × 2 1/2" × 3/4"	1
2	HOLDER	MAHOGANY	1 1/2" × 1" × 3/4"	2
3	DOWEL PIN	BIRCH	1" × 1/4" DIA.	2
4	LABEL	PLASTIC	4 1/2" × 3/8"	1
5	PADS	FELT	1/2" × 1/2"	4

OT #5-8

SPECIFICATION SHEET

ADHESIVE: USE WHITE GLUE TO FASTEN HOLDERS, DOWEL PINS, AND BASES TOGETHER. CLAMP FOR ONE HOUR. ALLOW TWENTY FOUR HOURS TO DRY.

FINISH: RUB IN TWO COATS OF TUNG OIL WITH A CLOTH. ALLOW TWENTY FOUR HOURS BETWEEN COATS.

OT #5-9

SPECIFYING THE DESIGN

Discussion:

During the research process, the goal was to gather information needed to solve a specific problem. During the development process, the goal was to create a product that will solve the problem. The next phase of the research and development process is called product engineering. During this phase, the goal will be to make the product that will solve the problem.

The first step in the product engineering process is to specify the design. The purpose of specifying the design is to determine how to make the product. When it is time to make the product, production people will need to know:

* how many parts to make.
* the size and shape of each part.
* what kind of material to use when making each part.
* how to put the parts together.

To specify a design, engineers draw a set of plans for the design using drafting tools or a CAD (computer-aided-design) system. Drawing a set of plans plays two important roles during the design specification process. First, they allow engineers to test their ideas on paper before they try to make the product. Second, they help the engineers tell the production people how to make the product.

If the design is entered into a CAD system, a computer simulation can be used to test the design and identify problems. When problems are discovered, the engineer can use the CAD system to improve the design. When the design is complete, the computer can be used to draw plans and/or program production equipment to manufacture the product.

The plans used to manufacture a product are called working drawings. Working drawings use a variety of communication tools to describe the product. Detailed drawings are used to show how to make each part. They typically show the part from a variety of views. Most detail drawings include a front, top, and side view of the part. Sometimes, detail drawings use a cut-away view to show details inside the part. Dimensions are used to describe the size and shape of the part.

Assembly drawings are used to show how the parts fit together. Assembly drawings help production people understand how to put the product together.

Schematic drawings are used to describe electrical or fluid power systems. Schematics use a variety of symbols to represent each component in a system. Lines are used to show how the components are connected tegether.

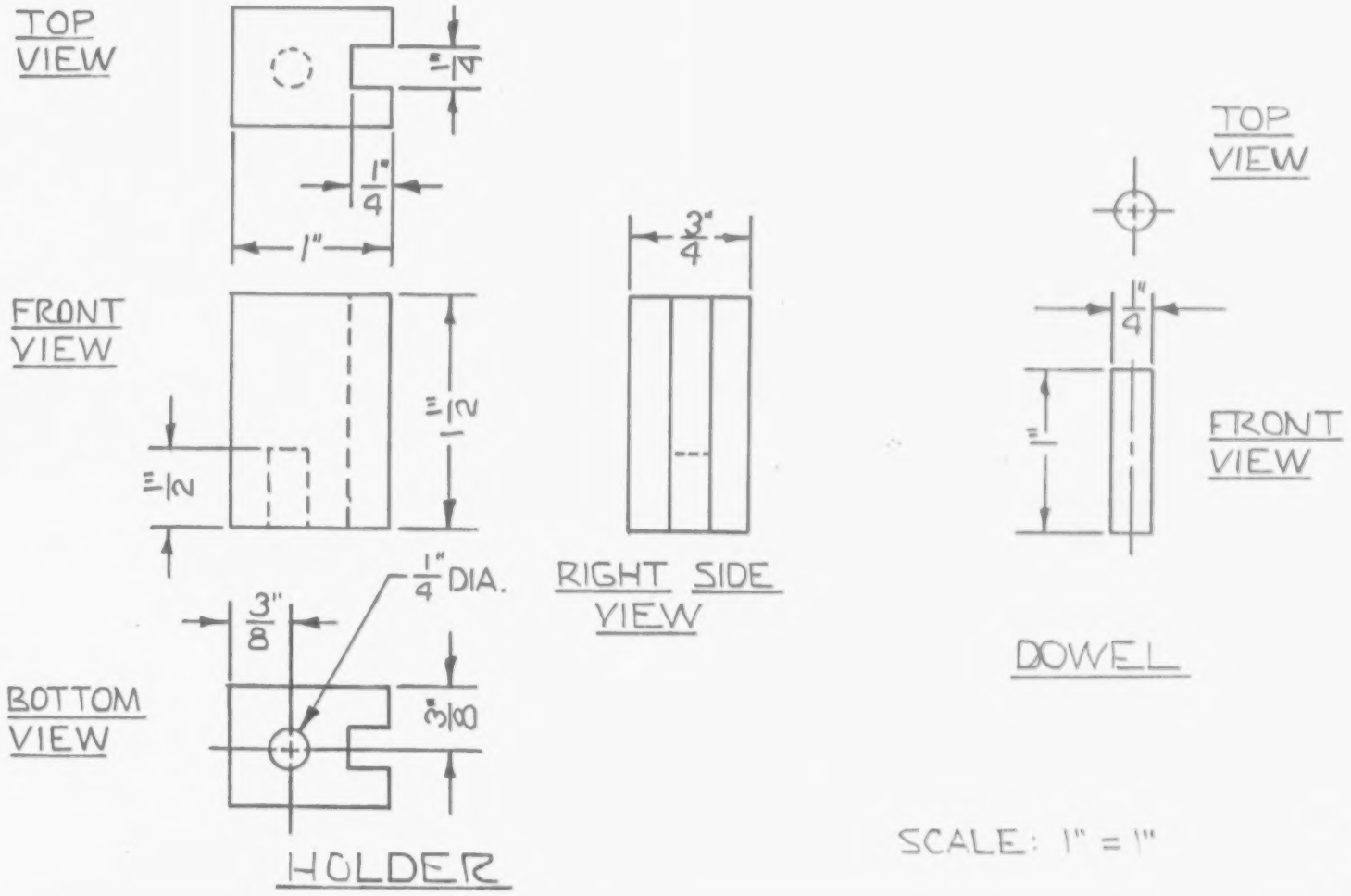
A bill of materials is used to describe materials needed to make each part. A bill of materials is basically a list of the parts needed to make the product. A bill of materials will list the name of each part, describe its basic dimensions, identify the material used, and list the quantity needed.

Notes and specifications are used to provide information that cannot be drawn. For example, you cannot draw the finish used to protect the product. You can describe what finish to use, how many coats to apply, and how long to let it dry in the notes or specifications.

The goal of product engineering is to build the product. The first step in building the product is to specify the design. To specify the design, product engineers use drafting tools or a CAD system to develop a set of working drawings. Working drawings describe the size, shape and features of the product. Production people will use the working drawing to program production machines to make each part and assemble the final product.

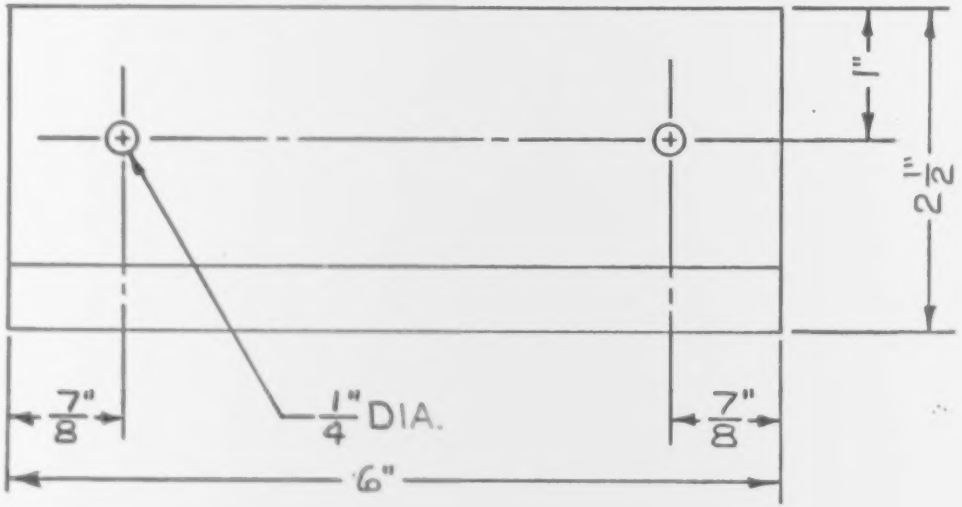
Learning Activity:

Directions: Your design team needs to specify the design by developing a working drawing, a bill of materials, and a specification sheet. You can divide these tasks among the members of your design team. For example, one or two team members can draw the plans, another team member can develop a bill of materials, and another team member can complete the specification sheet. Use your final sketch and your mock-up as a guide when specifying your design. In addition, you may want to refer to the examples provided for a business card holder.

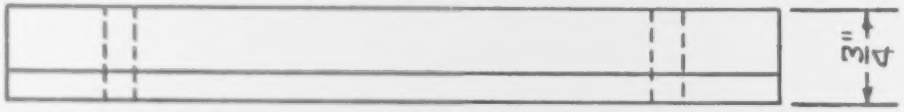


NAME: JOHN SMITH	BUSINESS CARD HOLDER	PART: HOLDER + DOWEL	DATE:

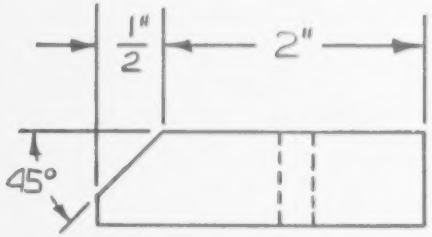
TOP VIEW



SCALE: 3/4" = 1"

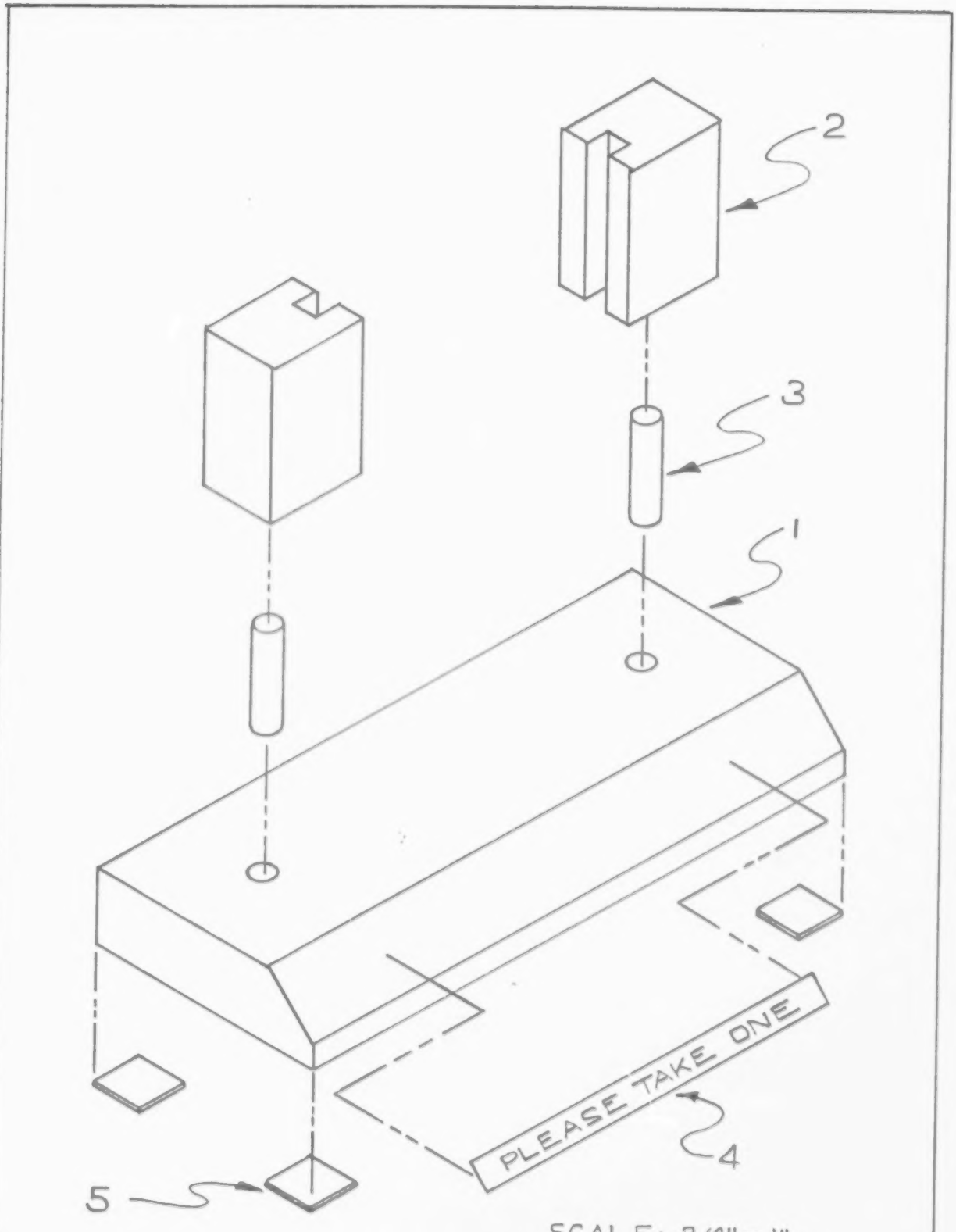


FRONT VIEW



RIGHT SIDE VIEW

NAME: JOHN SMITH	BUSINESS CARD HOLDER	PART: BASE	DATE:



SCALE: 3/4" = 1"

NAME: JOHN SMITH	BUSINESS CARD HOLDER	ASSEMBLY

BILL OF MATERIALS

PART NUMBER	PART NAME	MATERIAL	DIMENSIONS L×W×D	QUANTITY
1	BASE	MAHOGANY	6" × 2 1/2" × 3/4"	1
2	HOLDER	MAHOGANY	1 1/2" × 1" × 3/4"	2
3	DOWEL PIN	BIRCH	1" × 1/4" DIA.	2
4	LABEL	PLASTIC	4 1/2" × 3/8"	1
5	PADS	FELT	1/2" × 1/2"	4

SPECIFICATION SHEET

ADHESIVE: USE WHITE GLUE TO FASTEN HOLDERS, DOWEL PINS, AND BASES TOGETHER. CLAMP FOR ONE HOUR. ALLOW TWENTY FOUR HOURS TO DRY.

FINISH: RUB IN TWO COATS OF TUNG OIL WITH A CLOTH. ALLOW TWENTY FOUR HOURS BETWEEN COATS.

BILL OF MATERIALS

PART NUMBER	PART NAME	MATERIAL	DIMENSIONS L×W×D	QUANTITY

SPECIFICATION SHEET

Unit: Research and Development

Lesson 6: Building and Testing a Prototype

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify a definition for prototype. -list three basic reasons for building prototypes. -identify how prototypes are made. -identify the design considerations used to evaluate a prototype.	A. Building and testing a prototype 1. The first product made according to the plans is called a prototype 2. Prototypes are: a. custom made b. very expensive 3. Reasons for making prototypes a. to test the plans b. to test the design c. to learn how to manufacture the product 4. Basic design considerations when testing a prototype a. function b. appearance c. safety d. ease of servicing e. market appeal f. cost g. ease of manufacturing h. durability	A. Teacher Guided Discussion 1. Ask students what they think is the next step in the product engineering process. Using OT #6-1, discuss the definition of a prototype. 2. Using OT #6-2, discuss how prototypes are made 3. Using OT #6-3, discuss the three reasons for building prototypes. 4. Using OT #6-4, discuss how the basic design considerations apply to testing a prototype.	TA #6-1: Building and Testing a Prototype OT #6-1: Definition of Prototype OT #6-2: Prototype OT #6-3: Reasons for Making Prototype OT #6-4: Basic Design Considerations EO #6-1: Building and Testing a Prototype

B. Following a demonstration in a lab activity, students will be able to:
-utilize the working drawings they developed to build a working prototype.
-evaluate their prototype using the eight basic design considerations.

B. Building and testing a prototype
1. Building a prototype
   a. making components
   b. assembling components
   c. making adjustments
   d. documenting design modifications
2. Testing the prototype for:
   a. function
   b. appearance
   c. safety
   d. ease of servicing
   e. market appeal
   f. cost
   g. ease of manufacturing
   h. durability

B. Learning Activities
1. Using the plans provided for the business card holder or similar project, demonstrate how to use the tools and materials available to construct a prototype.
2. Once the prototype is complete, demonstrate how to create and conduct the tests necessary to assure product quality. Explain how to complete the prototype evaluation form.
3. Provide each student with HO #6-1.
4. Have students get into their design teams, return their working drawings, and have them begin developing their prototypes
5. Encourage and recognize teamwork.
6. Circulate around the room and provide individual instruction as needed.
7. Before the end of the period, provide each team feedback regarding their prototype evaluation.
8. Collect and evaluate each team's prototype and prototype evaluation form.

BUILDING AND TESTING A PROTOTYPE

Preparation Hints:

1. Review the materials provided, duplicate HO #6-1, and prepare the transparencies needed to present this lesson.

2. Consider making an example prototype. Making a prototype will help you anticipate problems, identify appropriate materials, and develop strategies for assuring students' success.

3. During the lab activity, your students will be making prototypes. If your students have not been introduced to the tools and materials in your laboratory, you will need to prepare several short lessons on using tools and machines to process materials.

4. Prior to implementing this lesson, you need to review each team's working drawings. Try to anticipate the tools, materials, and support materials your students will need to build and test their prototypes. For example, a team may need a video tape to test a video tape holder. Another may need a plexiglass cutter and a strip heater to make a plastic picture frame.

Content Presentation Hints:

1. When discussing prototypes, stress the importance of their role in testing working drawings, testing design, and planning the production process. Using the automobile industry for the context of your discussion, explain how prototype automobiles are subjected to a variety of tests. Include in your discussion things like road tests, endurance tests, crash tests, and market research. You may want to look through a variety of references on the automobile industry for pictures of prototypes for past models or concept cars of the future.

2. Consider showing a film or video tape featuring prototypes being tested.

Learning Activity Hints:

1. Using the working drawings provided for the business card holder, explain how to divide the task of building a prototype into making individual parts. Stress the importance of following the plans they developed. When

design flaws are discovered, explain how to document design modifications on the working drawings.

2. If your students are familiar with basic materials and processes, provide a short review emphasizing safety considerations when using the tools and materials in your laboratory. Provide individual instruction for those students who need to use special tools or materials to build their prototype. Explain how even automobile manufacturers sometimes have to hire a custom manufacturer to build their prototypes. Tell students you can serve as that custom manufacturer if they need to use machines that are off limits.

3. Using an example prototype, demonstrate how to create and conduct tests for each of the questions on the prototype evaluation form. You may want to refer to the example provided for the business card holder.

4. Your students may become frustrated with the quality of their prototype. Explain how the prototypes are custom made and do not benefit from the variety of jigs, fixtures, and quality control techniques used during the manufacturing process. Remind students that a prototype is not a finished product and the finished product will come off an assembly line. The primary purpose of the prototype is to test the working drawings, test the design, and plan the manufacturing process.

OT #6-1

The first product made according to the plans is called a prototype.

OT #6-2

Prototypes are:

* very expensive
* custom made

OT #6-3

Reasons for making prototypes:

* to test the plans
* to test the design
* to learn how to manufacture the product

Basic design considerations when testing a prototype:

* function
* appearance
* safety
* ease of servicing
* market appeal
* cost
* ease of manufacturing
* durability

BUILDING AND TESTING A PROTOTYPE

Discussion:

The first step in the product engineering process is called specifying the design. The goal is to determine how to build the product. During the design specification stage, a set of working drawings are developed. The next step is to actually build the product.

The first product built according to the plans is called a prototype. Since the production system has not been built yet, the prototype must be made by hand in a special facility. Because they are custom-made, prototypes are very expensive to build. A prototype for a new automobile can cost millions of dollars to build.

Prototypes play several important roles during the product engineering process. Product engineers use a prototype to test the plans, evaluate the design, and learn how to manufacture the product.

Product engineers use the working drawings drawn during the design specification process to build the prototype. If there are any mistakes on the drawings, the engineers building the prototype will find and correct them. Sometimes, design changes are made because the product engineers discover new and better ways to build the product while building the prototype. Just like drawing sketches, making mock-ups, and drafting plans, building the prototype represents another opportunity to improve the design.

Once the prototype has been built, the design can be tested. Sometimes, new products do not work as well in real life is they do on paper. Prototypes help product engineers discover and solve problems. If there are flaws in the product's design, product engineers want to find them during product testing. Problems not found during product testing are mass produced with the product. It is very expensive to solve problems once production begins.

Product engineers use the prototype to make sure the product works properly, is safe to use, is durable, and can be serviced easily. During product testing, prototype automobiles are driven on a test track and subjected to tests. These tests are used to evaluate things like handling, braking, acceleration, endurance, and comfort. Prototypes are often destroyed during safety tests. Sometimes, prototypes are shown at car shows to get public reaction to new designs.

Product engineers often help production engineers develop the production system used to manufacture a new product. Building the prototype helps the product engineer understand the relationship between various components. This experience can be very useful when planning a production line. Knowing how to build a product by hand is often the first step in learning how to build a product on an automated assembly line.

After the plans have been drawn, product engineers are ready to build the first product. The first product made according to the plans is called a prototype. Prototypes are custom-made and cost more to build than the final product. Prototypes can be used to test the plans, test the design, and learn how to manufacture the product.

Learning Activity

Directions:

1. Your design team needs to build and test a prototype. Using your plans as a guide, divide your product into specific parts. Each member of your team will build one or two parts. Make sure you build each part according to your plans.

2. After all the parts have been made, assemble them into a prototype. If the parts do not fit together as planned, identify the problem and make the necessary adjustments. Make sure you record all design modifications on your plans.

3. When your prototype is complete, it needs to be tested. Using the form provided, evaluate your prototype. Since each team's prototype is different, you will need to develop your own test for each question. After each test, answer the question and write a few comments in the space provided. Make sure your prototype meets your original design specifications. Refer to the example prototype evaluation form for ideas.

Prototype Evaluation Form

1. Is your product safe to use? (Yes or NO)

_____

_____

_____

_____

2. Is your product functional? (Yes or NO)

3. Can your product be serviced easily? (Yes or NO)

4. Is your product pleasant to look at? (Yes or NO)

5. Do people want to buy your product? (Yes or NO)

6. Is your product durable? (Yes or NO)

7. How much will it cost to make your product? $_____

8. Will your product be difficult to manufacture? (Yes or NO)

MARKET SURVEY

Directions: Show your prototype to a prospective customer. Allow them to hold the product and examine it carefully. After introducing yourself and asking permission to conduct the survey, ask them the questions listed below. Record their opinions by circling the most appropriate response under each item.

PRODUCT _____

CONSUMER INFORMATION

1. Type of person surveyed:

   A. Student
   B. Parent
   C. Teacher
   D. Other _____

2. Sex of the person surveyed:

   A. Male
   B. Female

MARKET INFORMATION

1. Would you purchase this product?

   A. Yes
   B. No
   C. Maybe

2. If yes, how many would you purchase?

   A. one
   B. two
   C. three
   D. other _____

3. What would you expect to pay for a product like this?

   A. 50 cents - $1.00
   B. $1.00 - $2.00
   C. $2.00 - $5.00
   D. More than $5.00

4. How could this product be improved?

   _____

   _____

Prototype Evaluation Form

1. Is your product safe to use? (Yes or NO)

   The product does not have any sharp edges. The felt pads protect the surface the business card holder sits on.

2. Is your product functional? (Yes or NO)

   Business cards can be removed easily as long as the holder is not overfilled. Displayed business cards are easy to read.

3. Can your product be serviced easily? (Yes or NO)

   The product should not need servicing. The "Please take one" label could be replaced if it falls off.

4. Is your product pleasant to look at? (Yes or NO)

   Our product looks good on most wood grain surfaces.

5. Do people want to buy your product? (Yes or NO)

   Eight out of ten people asked said they would buy our product.

6. Is your product durable? (Yes or NO)

   We pushed the product off a table three times. It did not break!

7. How much will it cost to make your product? $ 1.00

   We made our product out of scrap. It will cost about one dollar to buy the material needed to make one business card holder.

8. Will your product be difficult to manufacture? (Yes or No)

   The design is very simple. We were able to make the prototype with hand tools.

Unit: Research and Development

Lesson 7: Presenting a Design for Approval

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a discussion, students will be able to: -identify the goals of a product presentation. -list the four basic types of information provided in a product presentation. -identify the characteristics of a good product presentation.	A. Product presentations 1. Product presentation goals a. provide information about the product b. convince management to produce the product 2. Presentation content: a. product information b. market information c. financial information d. manufacturing information 3. Presenters should: a. plan carefully b. speak clearly c. be confident d. make eye contact e. use visuals f. anticipate questions	A. Teacher Guided Discussion 1. Ask students to list products that were developed but never manufactured. Discuss the need for management to approve a product before it can be manufactured. 2. Using OT #7-1, discuss the two basic goals of a product presentation. 3. Using OT #7-2, discuss the four basic types of information provided during a product presentation. Discuss some of the questions that have to be addressed during a product presentation. 4. Using OT #7-3, discuss the importance and characteristics of a good product presentation.	TA #7-1: Presenting a Design for Approval OT #7-1: Product Presentations OT #7-2: Presentation Content OT #7-3: Presenters HO #7-1: Presenting a Design for Approval HO #7-2: Peer Evaluation Form

B. Following a demonstration in a lab activity, students will be able to: -organize, prepare and present a product presentation that includes product, market, financial, and manufacturing information. -effectively use visuals to enhance their product presentation. -anticipate and answer questions about their product.	B. Making a product presentation. 1. Organizing, preparing, and presenting content. a. product information b. market information c. financial information d. manufacturing information e. summary 2. Using visuals a. displays b. sketches c. plans d. mock-ups e. prototypes 3. Anticipating and answering questions.	B. Learning Activity 1. Explain how a product presentation could be divided into topics. Explain how each member of a design team could address one topic. 2. Discuss the content that could be addressed for each topic. 3. Demonstrate how to conduct a product presentation. 4. Provide each student with HO #7-1. 5. Have students get into their design teams. Return their prototypes and prototype evaluation forms. 6. Have students begin organizing content and preparing visuals for their product presentations. 7. Circulate around the room and provide individual instruction as needed. 8. Allow students to rehearse their product presentations. 9. Ask each design team to make a formal product presentation. Have students complete a peer evaluation for each presentation.

10. After the last product presentation, ask students to vote on the product they would like to manufacture.
11. Collect the peer evaluation forms and ballots. Determine and announce the product that will be mass produced during the manufacturing unit.

PRESENTING A DESIGN FOR APPROVAL

Preparation Hints:

1. Review the materials provided, duplicate HO #7-1 and prepare the transparencies needed in order to present this lesson.

2. Consider inviting administrators, parents, guidance counselors, and teachers to your students' product presentations. For best results, have your students make and present the invitations.

3. Consider using the school's video tape equipment to record the product presentations. Your students can play the tape back and evaluate their own product presentations.

4. During the lab activity, your students will need to make visuals for their product presentations. Prior to implementing this lesson, you will want to collect a variety of materials for making visuals. You may want to include things like transparency film, magic markers, construction paper, contact cement, foam core, posterboard, and stencils.

5. You may want to consider providing sheets of fiber board, (sheathing material) for making displays. The fiber board can be painted or covered with paper. Thumb tacks can be used to fasten preliminary designs, final sketches, working drawings, and signs to the fiber board. Mock-ups and prototypes can be placed in front of the fiber board displays.

Content Presentation Hints:

1. When introducing the need to obtain management's approval to manufacture a product, discuss products that were developed but never manufactured. For example, your discussion could include things like the picture telephone, air bags, and electric cars. Ask your students if they can identify other examples.

2. When discussing the skills needed to make a quality presentation, try to reinforce the concepts taught in your language arts department.

Learning Activity Hints:

1. Use the business card holder or similar example to demonstrate how to divide a product presentation into topics, present the content appropriate for each topic, utilize visuals, and answer questions.

2. Ask students to complete a peer evaluation form after each product presentation. Use the peer evaluations in conjunction with your own evaluation when determining a grade for each product presentation.

3. When your students have finished their product presentations, consider displaying their problem statements, preliminary designs, final sketches, mock-ups, working drawings, and prototypes in a location where the rest of the school community can see the results of your students' creative problem solving activities.

OT #7-1

Product presentation goals:

* provide information about the product
* convince management to produce the product

OT# 7-2

Presentation content:

* product information
* market information
* financial information
* manufacturing information

OT #7-3

Presenters should:

* plan carefully
* speak clearly
* be confident
* make eye contact
* use visuals
* anticipate questions

PRESENTING A DESIGN FOR APPROVAL

Discussion:

Before a product can be manufactured, the people in research and development must get management's approval. The last step in the research and development process is to convince management the product works, people will buy it, and it will make the company a profit.

To convince management to manufacture a new product, a team of people from research and development make a formal presentation. During this presentation, they tell management about the new product. A typical presentation will include things like:

* why there is a need for the product.
* what makes the product useful.
* how their product compares with other products on the market.
* how long the product will last.
* who will buy the product.
* how much the product will cost to manufacture.
* the projected selling price for the product.
* how much profit can be made on each product.
* what kinds of tools, materials, and machines are needed to manufacture the product.
* what kind of human resources are needed to manufacture the product.

The presentation can be as important as the product's design when trying to convince management to manufacture the product. As far as management is concerned, the product can only be as good as the people who designed it. Management needs to know that the people who designed the product know what they are talking about and that they believe in their product and its design.

During the presentation, research and development people must become sales persons. Their presentation needs to be planned carefully. They need to speak clearly and with confidence. They need to use a lot of visuals (i.e., prototypes, drawings, plans, charts, graphs, pictures). They need to make eye contact with their audience. Lastly, they need to be able to anticipate and answer management's questions.

If management likes what they hear, they will give the "go-ahead" to manufacture the product. If management does not like what they hear, it is back to the drawing board to make modifications or to design a new product.

Before a product can be manufactured, management has to approve the design. To convince management to produce their product, a team from research and development needs to make a formal presentation explaining the merits of their product. The presentation will include product, market, financial, and manufacturing information.

Your design team has been working a long time to develop the best product possible. The other design teams in your class have also worked hard to develop good products. However, your class can only manufacture one product during your manufacturing unit. You need to convince the other members of your class that your product is the best product for your manufacturing experience.

Each design team will be given an opportunity to present the merits of their product. Your team needs to prepare a presentation that includes product, market, financial, and manufacturing information. You may want to assign each team member a topic. For example, one member of the team could present product information, another could present financial information, and so on.

The team member in charge of the product information could:

* state the problem.
* list the design specifications for the product.
* describe how your team went about solving the problem.
* discuss the solutions you considered (your preliminary designs).
* describe your final product design.

The team member in charge of market information could:

* describe the target market (the group of people for which the product is designed).
* summarize your market research information.
* discuss how your product compares with other products on the market.

The team member in charge of the financial information could:

* report how much it costs to make the product.
* discuss the product's projected selling price.
* estimate the profit margin for each unit sold.

The team member in charge of the manufacturing information could describe:

* the materials needed to make the product.
* the tools and machines needed to make the product.
* the processes needed to make the product.
* the people needed to make the product.
* how the product is assembled.

Your presentation could center around a display. The display could feature your problem statement, design specifications, preliminary designs, final product sketch, mock-up, market survey, and the prototype. During the presentation, team members could refer to the display. In addition, items from the display could be removed and passed around the class.

Lastly, one member from the group could make a short statement summarizing why your product should be mass produced during your manufacturing unit. At the end of your presentation, ask your audience if they have any questions.

When you have finished planning your presentation, conduct a rehearsal. During your rehearsal, practice your lines, speaking clearly, making eye contact with your audience, and using visuals. Take turns asking and answering questions. After all, "practice makes perfect."

PRODUCT PRESENTATION PEER EVALUATION FORM

Directions: After each product presentation, rate all of the presentation elements listed on the left on a scale of one to five.

Team Members: _____

_____

_____

_____

Product Presented: _____

1	2	3	4	5
very poor	poor	average	good	excellent

Presentation Content:

Product information	1	2	3	4	5
Market information	1	2	3	4	5
Financial information	1	2	3	4	5
Manufacturing information	1	2	3	4	5

Presentation Skills:

Use of visuals	1	2	3	4	5
Communication skills	1	2	3	4	5
Eye contact	1	2	3	4	5

Unit: Research and Development

Lesson 8: Evaluation

Objectives	Lesson Content	Learning Activities	Ref.
A. Following a review, on a written objective test, students will be able to complete given concept statements regarding research and development with a minimum of 70% accuracy.	A. Review 1. Identifying the problem 2. Gathering information 3. Developing preliminary designs 4. Selecting and refining a design 5. Specifying the design. 6. Building and testing the prototype 7. Presenting a design for approval	A. Teacher Guided Review 1. Review the major concepts explored during the unit. 2. Provide students with an opportunity to ask questions before taking the test. 3. Provide each student with HO #8-1 and make sure each student has a pen or pencil. 4. Explain the directions for the test. 5. Have students read the test and answer the questions provided. 6. Collect the tests and grade your students' performance. 7. Provide students with feedback regarding their test performance as soon as possible.	HO #8-1: Test

RESEARCH AND DEVELOPMENT TEST

Directions: Read each question carefully. In the blank provided, write the letter of the answer option which best completes or answers the question.

_____ 1. The first step in a design process is to _____.

A. select the best solution.
B. gather information
C. make a prototype
D. identify the problem

_____ 2. Which of the following is not a basic part of the product profile.

A. problem statement
B. thumbnail sketches
C. design specifications
D. company limitations

_____ 3. Which of the following is not part of the brainstorming process?

A. generating ideas freely
B. evaluating ideas
C. recording all ideas
D. teamwork

_____ 4. Research is _____.

A. a systematic way to solve problems
B. a systematic process for discovering and gathering information
C. using information to design a solution to a problem
D. preparing a design for manufacturing

_____ 5. Which of the following is a good source for information?

A. libraries
B. government agencies
C. industry
D. all of the above

_____ 6. Conducting research to learn more about a material (wood, metal or plastic) would be an example of _____.

A. applied research
B. pure research
C. product development
D. product engineering

_____ 7. During brainstorming activities, ideas are recorded in the form of _____.

A. detailed drawings
B. mock-ups
C. renderings
D. thumbnail sketches

_____ 8. The people in research and development must be able to _____.

A. generate new ideas
B. analyze new ideas
C. communicate new ideas
D. all of the above

_____ 9. A lifelike sketch of a new product is called a _____.

A. rendering
B. thumbnail sketch
C. rough sketch
D. working drawing

_____ 10. A prototype is _____.

A. made before the plans are drawn
B. the first product made according to the plans
C. mass produced on an assembly line
D. a hard mock-up of the proposed product

_____ 11. A hard mock-up of a stereo would not include

A. a tape transport
B. a station dial
C. the internal electronics
D. working switches and knobs

_____ 12. Which of the following can show a design in three dimensions?

A. thumbnail sketches
B. renderings
C. mock-ups
D. working drawings

_____ 13. The first step in the development process is to _____.

A. develop a variety of preliminary designs
B. build and test a prototype
C. develop a set of working drawings
D. develop renderings and mock-ups

_____ 14. The goal of product engineering is to _____.

A. prepare the design for manufacturing
B. discover and gather information
C. design a solution to a problem
D. all of the above

_____ 15. Which of the following communication tools is not used during the design specification process?

A. detailed drawings
B. assembly drawings
C. paste-up mock-ups
D. notes and specifications

_____ 16. Prototypes are built and tested during the _____.

A. development process
B. product engineering process
C. research process
D. brainstorming process

_____ 17. The type of drawing used to communicate the size and shape of a part is called a _____.

A. assembly drawing
B. schematic drawing
C. detailed drawing
D. notes and specifications

_____ 18. The primary reason for conducting a product presentation is to _____.

A. convince management to produce the product.
B. sell the product to the public.
C. gather information about the product.
D. test the product.

19. The people in research and development follow a basic series of steps when creating a new product. Put the following list of steps in their correct order by numbering them from 1 to 8.

_____ Make a prototype

_____ Gather information about the problem

_____ Present the new product to management

_____ Select the best solution

_____ Identify and analyze the problem

_____ Test and modify the prototype

_____ Develop a list of possible solutions

_____ Specify the design

REFERENCES

Fales, J., Sheets, E., Mervich, G., Dinan, J. (1986) Manufacturing: a basic text for industrial arts. Bloomington, IL: Bennett & McKnight.

Lux, D. G. & Ray, W. E. (co-director, IACP) (1971) The world of manufacturing (4th ed.) Bloomington, IL: McKnight.

Wright, T. R. (1986) Exploring Manufacturing. South Holland, IL: Goodheart-Willcox.

Wright, T. R. & Jensen, T. R. (1980). Manufacturing: material processing, management, careers. South Holland, IL: Goodheart-Willcox.

Page, R., Clarke, R. & Poole, J. (1982). Problem solving. Edinburgh, England: Oliver & Boyd.